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THE GRADUATION ERRORS OF A DIVIDED CIRCLE.

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FOR POPULAR ASTRONOMY.

The use of graduation error may appear to be a refinement beyond the requirements of ordinary practice, and the methods of its determination may seem to be extremely technical.

But there is always a certain amount of interest in showing how various conditions affect the results of observation. And, with respect to this determination, the problem as presented in the case of a meridian circle, with two graduated arcs, is one that can be easily made intelligible in plain language, and without complicated formulæ.

As to the effect in meridian circle work, it is evident that the observed place of a star will be affected by the same amount of error due to graduation as long as the same division of the circle is used for the observation. The effect of precession and declination may eventually change the zenith distance by an amount equal to the graduation interval, and the observation of the stars' zenith distance will be transferred to another division of the circle. In most instruments the circles are graduated to every 2′, and precession at 0^h and 12^m will amount to half that interval in the course of three years. The problem of actually measuring the errors of all the 2′ divisions may be considered as quite beyond the ability of any one observer, giving to the measurement the time necessary to attain the precision desired.

For, first of all, the method of measuring the error having been worked up, it will be evident that there will be no practical utility in making the measurement unless the precision of the results is in due proportion to the size of the quantity to be measured. This is where a halt must be called in the process of measurement.

The determination of the corrections soon gives an idea of the approximate size of the actual errors made in placing the divisions upon the circles. The error of determination should not exceed half the average size of the quantities to be measured. This may be safely placed as the upper limit. To be of standard value, the errors of measurement should be well within that limit.

The error of measurement should be clearly defined. Every determination of a quantity by practical means of measurement has an error, whether the quantity be one of capacity, of lineal distance, or of angle. The effect of the error of measurement can be diminished by repeating the measures.

In the case of a direct comparison, where the lineal or angular distance can be actually placed beside the standard, the error of comparison is likely to be very small; especially if the difference from the standard is not great.

In the measurement of graduation errors of a meridian circle, while we are accustomed to speak of the comparison of two arcs, it must be understood that the arcs are not placed alongside, directly, but are each one at one of the extremities of the telescope axis; and the comparison is made by reading the circle microscopes in various positions of the instrument.

If the arc included between two divisions is liable to have an error of $\pm 0''.2$, due to graduation, unless our means of measurement gave greater precision than $\pm 0''.2$ there would be no practical gain in making the investigation, for the purpose of applying corrections.

The error of our measure should not exceed $0''.1$ as a practical working limit; and should be smaller still, if we are striving for fine results in the angles for which we are to use the graduated arc.

This is very nearly the form in which the measurement of the division errors of the Repsold Meridian Circle of the Lick Observatory presents itself. Until the size of the division errors, likely to have been made in graduating the circles, was known, no idea of the precision of the measured declinations of the stars was established. The errors found thus far, in the investigation of the 1° arcs, are of about this size.

The results of a completed investigation have given the probable error of the graduation of a division on one circle as $\pm 0''.15$; and $\pm 0''.18$ for the other circle; for the mean of four divisions. The errors of these divisions had been determined with a probable error of measurement not exceeding $\pm 0''.05$. Single divisions would probably be subject to graduation errors of double the errors of the mean of four.

An angle, measured between two divisions, each of which has probable error of graduation of $\pm 0''.15$, would evidently be subject to a probable error of $\pm 0''.2$.

But it is evident that only angles which were even degrees in length could be improved by the application of these corrections.

Had there been evident any periodic character in the graduation errors, the intermediate divisions might have been improved to some extent. In the absence of evidence of periodic character, it is doubtful if anything would have been gained by interpolating values of the corrections for the intermediate divisions.

The star declinations would be affected in either one or two ways, by the existence of uncorrected graduation errors. If the fixed circle were constantly used for the same star, every observation, and in general the mean of all the observations of that star, would have a constant error. If the declination is determined by the use of several fundamental stars, the mean of the graduation errors of these stars enters into the error of the star observed; but the ultimate effect upon the declination is mainly due to the graduation error of its own division on the circle.

If the movable circle is used, and shifted on its axis for every observation, the mean result for the declination of a star would still be affected by graduation error. But the amount would be diminished by the calculated effect of accumulating a number of measures, each subject to accidental errror.

This is a fair illustration of the effects of systematic and accidental errors. Until graduation errors are known, the declination cannot be cleared from their influence; but the probable size of the declination errors, due to this source, may be determined.

In determining the latitude, the value from each star is affected by the graduation error of the division used for the star. And as the whole series, in each position of the instrument, is measured from the circle reading when the telescope is pointed to the Nadir, each series will be subject to a constant error, that of the graduation error of the Nadir reading; and the two series, in reversed positions of the instrument, will differ by double the amount of this particular graduation error.

In so-called fundamental declinations, this graduation error of the Nadir reading is eliminated, in effect. For the latitude is determined by observing fundamental stars, usually circumpolar stars at both culminations; and this latitude is then used as a reference point for obtaining the declinations of other stars, by measuring their zenith distances. In other words, though our reference point may be in error, the difference in angle from that reference point to the stars is not affected.

The variation of latitude is not confused by the effect of graduation errors, since the same divisions are used for the Nadir, or zenith point; and for the same star, the same divisions will be in use for a period of considerable duration.

Graduation errors of a periodic nature are nearly eliminated from a strictly differential determination of star places. Thus the Gesellschaft zones should not be subject to periodic errors from this source.

There is a rather curious paradox, to be kept in mind when treating of this matter of graduation errors, and its effect upon the measure of angles. It is well known to all who have had to deal with the subject, undoubtedly. The usual process of determining graduation errors, is to assume some division as a base, and to measure the errors of the other divisions, in angular terms from the base. If we call the *error* of a certain division, thus measured, $+ a$, then the *correction* to the actual arc is $+ a$.

This will appear to be perfectly self-evident, and yet it appears to confuse our ideas of errors and corrections, which are ordinarily reckoned as distinctly opposite in character, and use. Confusion in statement is constantly occurring; and the application of corrections for graduation has been complicated.

A safe and simple method has been used here, for graduation corrections, as well as for those of flexure, and all other declination terms. From the beginning, graduation corrections are considered as applicable to circle readings directly. They are not then confused with the ultimate effect upon the angles to be measured, such as zenith distance and declination. Flexure, if very small, as it is in this instrument, may be easily confused in sign, when considered in its effect upon zenith distance. But by adopting, from the original observations, the direct effect upon the circle readings, it appears easy to keep it free from doubt. Of course one can always work out the proper application; the point which it is designed to make plain, being, that this simple way of considering only the circle reading itself, is the shortest, and once settled upon there is no need to renew consideration of the corrections.

Refraction corrections are so large that they are not likely to be applied with the wrong sign. Still, a good way to consider them is in the sense of corrections to circle readings, changing sign at the zenith.

For declinations measured with the meridian circle here, it will be safe then to predict, that for any star the probable error to be anticipated from the effect of graduation will amount to less than $\pm 0''.2$.

If the graduation errors of the divisions employed for two stars could be determined with a probable error of $\pm 0''.05$ each, then the difference of declination would have a probable error of $\pm 0''.07$.

For stars determined with a series of fundamental stars as a basis, the ultimate effect upon the stars would be less than $\pm$ 0.″07, if all the graduation errors were ascertained with the same precision; but it would not be less than $\pm$ 0.″05.

The measurement of the graduation errors already made has given us this much information; and for the 1° arcs, there appears to be no periodic character. Further subdivision will show whether the intermediate divisions are as well placed, in respect to accuracy, and whether there is periodicity in the errors.

To take up the process of measuring the graduation errors. It is first necessary to have a scale with which to compare the arcs. In lineal measure there are various standards employed, and no matter whether yard, metre, or vara be used, the relation of one to the other is well known. Nearly every civilized government has its standards of measure, carefully made and tested, and carefully preserved, while always available for test and comparison. The greatest refinement is necessary in the preparation of these standards of length.

When we come to the question of angular measure, we can easily derive our own exact standard. If we divide a circumference into a dozen parts, nearly equal, and compare each of these parts with another circle upon which an arc of about the twelfth part—more or less—has been laid off, we can find the exact angular value of this last arc, with a precision only limited by the accuracy of our comparisons. We may find that one of our dozen parts is 1″ longer than the arc we are measuring; and that another part is 15″ shorter; and so on through the entire dozen. If we sum up the differences and divide by twelve, the result will show precisely how much the arc to be measured was greater or less than 30° in length. For the sum of our twelve parts must be precisely a perfect circle.

We can now turn back to our comparisons, and, knowing the exact length of the arc we have determined, we can obtain the exact length of each of our twelve parts of the original circle; always taking for granted that we can measure precisely the difference between the arcs of each circle under comparison. This difference can be quite precisely measured in the case of our instrument, with two circles attached. That is to say, the precision depends upon that of the reading of the circles, under the microscopes, and greater precision in the final result can always be attained by increase of the number of microscope readings. There is, of course, a practicable limit to the number of readings for any particular arc. In order to complete the whole circum-

ference, one cannot devote too great an amount of time to a limited number of divisions.

And it eventually becomes impracticable to divide the circle into a great number of parts, the sum of which shall be a complete circumference, and to observe all the parts consecutively in one series. It has been found best in practice to limit the duration of a series to about one hour; starting a new series, perhaps immediately upon the conclusion of the first, but avoiding the element of change in the relative positions of microscopes, and of the circle itself, which we are aware may take place after a considerable lapse of time. For short intervals of time these changes are proportionally small. And they are controlled by reading forward and back in each series, thus eliminating any changes of purely progressive character. Reading each circle twice, at each setting, eight or nine settings forward, and the same number in the reverse direction, about fill an hour of readings.

The determination of the 15° arcs makes a good illustration of the complete series; and one that has recently been made here, as a check upon earlier work, and to obtain a certain amount of practice for further subdivision, will serve our purpose.

The following explanation will, it is expected, make plain the successive steps in the necessary observation and reduction.

First for the 15° series.

The movable circle is set so that the zero of each circle comes under its corresponding microscope simultaneously. As both circles are graduated in the same direction, while they face east and west respectively, in position, it is clear that one increases for a movement of the telescope, at the same time that the other diminishes. If the telescope is moved so that circle A reads 15°, then circle B will read 345°; and when A reads 30°, B will read 330°; both being fixed to the axis of the telescope. The sum of the readings of A and B is then a constant, during the time that each is clamped to the telescope, except for the errors of each circle, including graduation and flexure. Eccentricity is eliminated from the mean of four microscopes. And the effect of circle flexure can be eliminated by reading through opposite quadrants as in the series under observation.

If we let the small letters represent the graduation errors of the respective divisions, and let C represent the observed sum of the readings, the first series of observations would be put in the following form:

$$\begin{array}{ll} A + a\ 0° + B + b\ 0° = C_1 & A + a\ 45° + B + b\ 315° = C_4 \\ A + a\ 15 + B + b\ 345 = C_2 & A + a\ 60 + B + b\ 300 = C_5 \\ A + a\ 30 + B + b\ 330 = C_3 & A + a\ 75 + B + b\ 285 = C_6 \end{array}$$

The mean of the series of observed sums, C_0, would consist of the sum of A and B and one-sixth of the combined graduation errors of the six divisions of each circle.

By shifting one circle on its axis, by fifteen degrees, there would result a series of the next following form.

$$\begin{array}{ll} A + a\ 0^\circ + B + b\ 345^\circ = C^1_1 & A + a\ 45^\circ + B + b\ 300^\circ = C^1_4 \\ A + a\ 15 + B + b\ 330 = C^1_2 & A + a\ 60 + B + b\ 285 = C^1_5 \\ A + a\ 30 + B + b\ 315 = C^1_3 & A + a\ 75 + B + b\ 270 = C^1_6 \end{array}$$

The mean would again consist of the sum of A and B, and one-sixth of the same graduation errors as before; noting that the graduation error of 270° is the same as that for 180°, 90° and 0° when the circles are read upon all four microscopes; and similarly for the other readings ninety degrees apart. Taking out the residuals of each equation, we should have the following two sets of equations, to compare, for the correction to circle A at 15°.

$$\begin{array}{ll} a\ 0 + b\ 0 = C_0 - C_1 = m_1 & a\ 15 + b\ 345 = C_0 - C_2 = n_1 \\ a\ 0 + b\ 345 = C_0^1 - C_1^1 = m_2 & a\ 15 + b\ 330 = C_0^1 - C_2^1 = n_2 \\ a\ 0 + b\ 330 = m_3 & a\ 15 + b\ 315 = n_3 \\ a\ 0 + b\ 315 = m_4 & a\ 15 + b\ 300 = n_4 \\ a\ 0 + b\ 330 = m_5 & a\ 15 + b\ 285 = n_5 \\ a\ 0 + b\ 285 = m_6 & a\ 15 + b\ 270 = n_6 \end{array}$$

and, subtracting the sum of one set from the other:

$$6a0^\circ - 6a15^\circ = \Sigma m - \Sigma n.$$

This gives the correction for graduation of A 15°, with respect to A 0°.

Thus the difference between the corrections to A at 15° and A at 0° results from the simple summation of the residuals, or from the residuals of the sums of all the sets. Similarly for each 15° of arc. And the corrections derived are evidently independent of the graduation errors of circle B. These may in turn be derived in an entirely similar manner.

This is the customary way to investigate the graduation errors, when the whole circumference can be divided into equal parts, and the entire number of divisions can be observed in one set.

The determination of the division which is to serve as a base, forms part of such an investigation. The correction of each division is then given, usually with the adoption of a fixed value for the base, such as zero, or the average of all the errors; or often, a large enough value to make all the corrections of the same sign. It is clear that any particular correction will be given in the form of the difference between the corrections for that division, and the correction determined for the base.

But it is desired to illustrate the method of deriving the graduation errors of such a series, which shall be more nearly like that used in smaller subdivisions of the circle.

Accordingly we can write, from the first series, the following difference:

$$a\,15° + b\,345° - a\,0° - b\quad 0° = C_2 - C_1 = p_1$$

And from the second series:

$$a\,15° + b\,330° - a\,0° - b\,345° = C'_2 - C'_1 = p_2$$

And similarly

$$\begin{aligned} &a\,15° + b\,315° - a\,0° - b\,330° &&= p_3\\ &a\,15 + b\,300 - a\,0 - b\,315 &&= p_4\\ &a\,15 + b\,285 - a\,0 - b\,300 &&= p_5\\ &a\,15 + b\,270 - a\,0 - b\,285 &&= p_6 \end{aligned}$$

Summing up the above we shall have:

$$6a15° - 6a0° = \Sigma p :$$

and the graduation error of A15°, as measured from A0°, is derived independently of the arcs of B, which have been used as steps in the measurement.

Similarly: $$6a30° - 6a0° = \Sigma q :$$

and so on for the five 15° divisions of circle A.

The computing process can then be repeated for circle B, and the graduation errors of each 15° division, with respect to the zero division of circle B, will have been determined independently.

The accuracy may appear to be less than if the residuals were taken originally from the mean. But in that case, the graduation error of 0° has to be determined by the residual from the mean, and the graduation error of 15° is finally derived from the difference of the two respective graduation errors first determined. The results, and the precision, are identical for the two methods of computing the corrections.

The computation of one of the 15° arcs, in the recent investigation, will illustrate the process. The equations have been transformed into the most convenient form for computation, the numbers corresponding to the *m* of the original set in the preceding reduction.

°	″	°	°	°	″	″
a 15 =	+ 0.25	− b 75	+ a 0	+ b 90 =	+ 0.54	v − 0.12
a 15 =	+ .67	− b 60	− a 0	+ b 75 =	+ .72	+ .06
a 15 =	+ .89	− b 45	+ a 0	+ b 60 =	+ .59	− .07
a 15 =	+ .61	− b 30	+ a 0	+ b 45 =	+ .73	+ .07
a 15 =	+ .80	− b 15	+ a 0	+ b 30 =	+ .71	+ .05
a 15 =	+ .73	− b 0	+ a 0	+ b 15 =	+ .66	.00
Mean	+ 0.66				+ 0.66	± 0.06

The derivation of the mean first obtained above is as far as the computation is required to be carried, since the graduation errors of B evidently are eliminated from the summation. For complete illustration, however, the graduation errors determined in this investigation, for all the B divisions, have been applied, and the actual observed errors of A 15° appear in the column above the second mean, with the residuals.

The corrections derived for the two circles are given below, along with those of the original investigation, made in 1895, with the assistance of Mr. R. G. Aitken. The present sets were observed with Mr. Elliot Smith, and contained but six determinations of each division; while the earlier series included twenty-four.

°	1895. ″	1903. ″	°	1895. ″	1903. ″
A 0	+ 0.19	+ 0.39	B 0	+ 0.11	− 0.15
A 15	− .18	− .27	B 15	− .21	− .08
A 30	− .04	+ .08	B 30	− .05	+ .01
A 45	− .44	− .48	B 45	.00	− .10
A 60	+ .24	+ .17	B 60	+ .15	+ .19
A 75	+ .25	+ .12	B 75	− .02	+ .14

In the present series, each observer read both circles at every setting, and this makes it possible to determine the probable error at every stage of the process. By comparing the individual microscopes, the p. e. of a single reading is found to be ± 0″.30, without distinction of observers, based upon 576 residuals. This is larger than usually found in my own observing, but includes some outstanding personal difference. By comparing the separate circle readings, the p. e. of a circle reading is found to be ± 0″.13: again without distinction of observers, from 144 residuals. The p. e. of the sum of opposite circles is ± 0″.25, including any change in the relative position of either, during one series of settings forward and back. This is based upon 72 residuals. By comparing the mean of forward and back, for each observer, the p. e. of the mean of four circle readings is ± 0″.15, based upon 36 residuals. By correcting the readings and comparing the results, the p. e. for the mean of both observers is ± 0.″08, from 36 residuals.

By the separate values of the final division errors, 60 residuals in groups of five, the p. e. of a determination is ± 0.″13; and for the mean of six determinations will be ± 0.″05. The probable error at each stage can be carried forward, to predict the p. e. of the final result. Thus, the

p. e. of one microscope gives	± 0.″15 div. corr.
p. e. one circle reading	± 0. 13
p. e. sum of both circles	± 0. 18
p. e. mean forward and back	± 0. 15
p. e. mean both observers	± 0. 11
Final p. e. from separate values	± 0.″13

Next, it is proposed to illustrate the method of measuring graduation errors for the divisions, which are so near to each other, that a series of such arcs cannot be extended throughout the whole circumference. The 10′ arcs are selected for the purpose. The method of observing is similar to the above, except that a series extends only through one degree, and return, with readings at every 10′. This makes an observation series of fourteen double circle readings, upon each circle, and requires a little less than an hour for the simultaneous work of two observers, including the shifting of the movable circle for each series.

The 10′ divisions of Circle A are to be determined, using as bases for each, the graduation corrections of the 1° divisions each side, which have been previously measured. The standards with which each 10′ arc is to be compared are the six 10′ arcs of one degree of Circle B. These six comparison arcs are to be determined with very high degree of precision, and quite independently of any error of standard.

Following the process last outlined, for the 15° arcs, we have the following equations:

$$
\begin{array}{llllllllll}
a\,1^\circ\,10' & = & -\,0''.10 & - & b\,0^\circ\;\;0' & + & a\,1^\circ\,0' & + & b\,0^\circ\,10' \\
a\,1\;\;10 & = & -\;\;.59 & - & b\,0\;\;10 & + & a\,1\;\;0 & + & b\,0\;\;20 \\
a\,1\;\;10 & = & -\;\;.08 & - & b\,0\;\;20 & + & a\,1\;\;0 & + & b\,0\;\;30 \\
a\,1\;\;10 & = & -\;\;.42 & - & b\,0\;\;30 & + & a\,1\;\;0 & + & b\,0\;\;40 \\
a\,1\;\;10 & = & -\;\;.07 & - & b\,0\;\;40 & + & a\,1\;\;0 & + & b\,0\;\;50 \\
a\,1\;\;10 & = & -\;\;.46 & - & b\,0\;\;50 & + & a\,1\;\;0 & + & b\,1\;\;0. \\
 & & & & & & & & \\
a\,1\;\;10 & = & -\;\;.48 & - & b\,0\;\;50 & + & a\,2\;\;0 & + & b\,0\;\;0 \\
a\,1\;\;10 & = & -\;\;.50 & - & b\,1\;\;0 & + & a\,2\;\;0 & + & b\,0\;\;10
\end{array}
$$

The above will give eight values for A 1° 10′: of which six depend upon the correction already determined for A 1° 0′, and two upon that of A 2° 0′. And all of the 10′ arcs of B enter the solution, though evidently all but two, B 0° 50′ and B 0° 10′, will be eliminated in the mean.

For each 10′ division, except that at 30′, there will be two 10′ graduation errors of B uneliminated; but at 30′, all the errors of B disappear in the summation.

When the 10′ errors of B have been entered, the individual solutions can be made of the eight values. And, finally, all the corrections having been entered, a solution can be made for each 10′ division, which will depend upon all the observed readings for seven sets, 49 double readings of both circles by each observer.

There are, besides, always two solutions for each 1° division, determined from the adjacent 1° divisions of circle A.

$$
\begin{array}{llllllllll}
a\,2^\circ\,0' & = & +\,0''.12 & - & b\,0^\circ\,1' & + & a\,1^\circ\,0' & + & b\,1^\circ\,0' \\
a\,2\;\;0 & = & +\,1\;\;.05 & - & b\,1\;\;0 & + & a\,3\;\;0 & + & b\,0\;\;0
\end{array}
$$

Thus the solution for the even degree divisions will depend entirely upon single degree divisions of Circle A, the errors of B being eliminated. For the 10′ arcs, circle flexure need not be considered, the determination, confined to a small arc, being of a differential nature.

The intermediate 2′ divisions can be measured from the nearest 10′ divisions should it be deemed necessary. This process will probably only be carried out for specially desired graduation errors.

It only remains to show how the 10′ divisions of Circle B, used as standards, are to be determined.

Let us take first a single series of observations:

$$\begin{array}{llll} A+a\,0^\circ\,0' & +B+ & b\,1^\circ\,0' & =C_1 \\ A+a\,0\,10 & +B+ & b\,0\,50 & =C_2 \\ A+a\,0\,20 & +B+ & b\,0\,40 & =C_3 \\ A+a\,0\,30 & +B+ & b\,0\,30 & =C_4 \end{array} \qquad \begin{array}{llll} A+a\,0^\circ\,40' & +B+ & b\,0^\circ 20' & =C_5 \\ A+a\,0\;\;50 & +B+ & b\,0\,10 & =C_6 \\ A+a\,1\;\;\;0 & +B+ & b\,0\;\;0 & =C_7 \end{array}$$

Then for the error of B 0° 50′ we can write the difference:

$$a\,0^\circ\,10' + b\,0^\circ\,50' - a\,1^\circ\,0' - b\,0^\circ\,0' = C_2 - C_7 = r$$

and

$$b\,0^\circ\,50' = r - a\,0^\circ\,10' + a\,1^\circ\,0' + b\,0^\circ\,0'$$

From the similar succeeding series there will result:

$$\begin{array}{rrrrrrrrr} b\,0^\circ\,50' = & -0''.03 & -a\,0^\circ & 20' & +a\,1^\circ & 10' & +b\,0^\circ & 0' \\ \text{“} \quad - & .07 & -a\,0 & 30 & +a\,1 & 20 & +b\,0 & 0 \\ \text{“} \quad + & .55 & -a\,0 & 40 & +a\,1 & 30 & +b\,0 & 0 \\ \text{“} \quad - & .26 & -a\,0 & 50 & +a\,1 & 40 & +b\,0 & 0 \\ \text{“} \quad - & .18 & -a\,1 & 0 & +a\,1 & 50 & +b\,0 & 0 \\ \text{“} \quad - & .48 & -a\,1 & 10 & +a\,2 & 0 & +b\,0 & 0 \\ \text{“} \quad + & .28 & -a\,1 & 20 & +a\,2 & 10 & +b\,0 & 0 \\ \text{“} \quad - & .50 & -a\,1 & 30 & +a\,2 & 20 & +b\,0 & 0 \\ \text{“} \quad - & 1.16 & -a\,1 & 40 & +a\,2 & 30 & +b\,0 & 0 \\ \text{“} \quad + & .19 & -a\,1 & 50 & +a\,2 & 40 & +b\,0 & 0 \\ \text{“} \quad - & .27 & -a\,2 & 0 & +a\,2 & 50 & +b\,0 & 0 \\ \text{“} \quad + & .90 & -a\,2 & 10 & +a\,3 & 0 & +b\,0 & 0 \end{array}$$

No matter how far we carry this system of equations, there will be five graduation errors of A of minus sign, and five of plus sign, not eliminated from the sum, until we reach the end of the circumference; or what is the same thing for our purpose, the end of 90°, for the mean of four microscopes.

The last five series will close up the circuit of divisions, and the graduation errors of A of plus sign will cancel with those of minus sign. The 10′ division of B will thus have its value determined, independently of whatever errors the 10′ divisions of A may contain. The mean values of B will depend upon 540 such equations, for each 10′ division. The probable error of the measurement of the 10′ arcs of B may confidently be expected to be less than $\pm$ 0″.01. Such standards may well be defined as of

high precision. And as stated in the derivation of the 10′ corrections for A, the graduation errors of B are very nearly eliminated in the final results.

It is the illustration of our circle divided into twelve approximately equal parts. The single arc—on B—has been determined without dependence upon the individual errors of the arcs of the other circle.

Once our standard has been measured, we can use it to correct the separate aliquot parts of the other circle. And by repeating the measures, in the form of this investigation, in the mean of seven values, only two of our separate standards, at most, appear.

Of course, the full effect of the errors of measurement of the original 1° arcs will enter into the result of the new subdivision into 10′ arcs. As long as we can divide the circumference into parts that can be included in one set of observations, we need have no recourse to adopted corrections. For the small arcs, the best we can do is to measure differentially from points, whose graduation corrections have been already determined.

THE AURORA OF AUGUST 21, 1903.

JUDSON B. COIT.

For Popular Astronomy.

The phenomenon described by Rev. F. Campbell in the November number of Popular Astronomy was observed by me at Cape Porpoise, upon the coast of Maine.

That it was an auroral display, I did not for a moment doubt. The following account is taken directly from notes, dictated to an assistant, while the phenomenon was under observation.

At $8^h\ 20^m$ E. M. T. an auroral arch was seen extending from N.W. to N.E. rising in the center about 20° above the horizon. It was not particularly brilliant, was unattended by streamers and, in general, was in no way at all remarkable.

At $9^h\ 40^m$ my attention was called to a beautiful band of light rising from the western horizon at a point about 10° N. of W., passing a little south of Arcturus, thence on some 10° south of Vega (*i. e.* about 15° south of the zenith) and extending nearly to the horizon at a point a little south of east. When first seen the band was estimated to be about 2° wide, but narrower near the horizon. At $9^h\ 45^m$ the portion extending from a little above Arcturus to near Vega was described as being decidedly the

brightest, but in other respects at this time, the western half presented no marked peculiarities being essentially continuous and remarkably uniform in width. The part reaching eastward from Vega some 40° presented, however, at this time, as when first seen, a very different appearance. Here, the band, instead of being continuous, consisted of segments or sections separated by relatively dark strips. These segments seemed to lie absolutely parallel to one another and at an angle of 45° with the general direction of the band, *i. e.*, they lay nearly in the direction N.W. to S.E.

By $9^h\ 50^m$ the entire arch had swung to the south a distance equal to it own width, but still rested upon the horizon at apparently the same points. At this time it was noted that the entire eastern half was breaking into segments, that the western half was no longer of uniform brilliancy and that the band as a whole was declining in brightness.

At $9^h\ 55^m$ it was estimated that the southward drift had amounted to one and one half times the apparent diameter of the "Northern Crown." At this time the entire eastern half had become broken into segments all lying parallel to those described above as noted at $9^h\ 45^m$. This division into parallel segments did not appear at any time to the west of Vega. After $9^h\ 55^m$ the decline in brightness was rapid, the eastern portion fading more rapidly than the western. During this decline the parallel segments became more widely separated, increased decidedly in length, but all maintained to the last the same direction as when first noted.

At 10^h the entire band was nearly lost to view.

The general color of the band was noted as white with a light green tinge.

At $9^h\ 45^m$ the display which was noticed in the north early in the evening was still to be seen though it was very diffuse and faint. With the exception of this unimportant display, the band which spanned the heavens from W. to E. was the only aurora to be seen. Nothing was noticed in the way of pulsations or wave motion, although attention was carefully directed to these features so often present. There were no artificial lights to interfere with the observations.

As indicated by Mr. M. A. Veeder, observers of auroral streamers and bands need not be surprised if the directions assumed depart noticeably from those indicated by theory.

March 15, 1898, I observed* an auroral display which illustra-

* Journal of British A. A. VIII; 7.

ted this in a marked degree. At first it consisted chiefly of a belt of light some 20° wide and coinciding nearly with the ecliptic. Later there appeared streamers and isolated areas of aurora to such an extent that, at one time, fully 80 per cent of the visible heavens were covered. The present increase in solar activity will doubtless be accompanied with a revival in the appearance of aurora.

BOSTON UNIVERSITY,
Oct. 30, 1903.

ARE OTHER WORLDS INHABITED?

DANIEL E. WING.

FOR POPULAR ASTRONOMY.

It is the present purpose briefly to outline the argument respecting, (1) physical conditions which may, and probably do, result in habitability as the consequent effect produced in matter by the operation of natural laws, and (2) the origin of life, and its appearance upon a planetary body as a result of the operation of the same laws. To support such argument resort must be had very largely to observed conditions as they exist on known bodies.

Matter is ever integrating or disintegrating. Motion is continuous. Permanence of position or a state of rest does not exist. A body in which molecular motion is increasing rises in temperature, expands in volume, disintegrates first to a liquid and then to a gaseous form. A body of gas in losing heat contracts in volume and passes to liquefaction which would be followed by solidification if absolute rest were conceivable, but temperature being never fixed matter and motion must ever undergo redistribution.

What do these general propositions lead to?

We start with a body of gas which through loss of heat is contracting upon itself. We observe the body with a spectroscope and learn with reasonable certainty that in its composition are at least many of the elements with which, and with the effects of which in combination one with another, we are familiar. We observe a body, originally a part of the same mass of material but which by reason of smaller bulk has advanced farther in the process of integration, and we find it surrounded by a dense cloud-laden atmosphere having the fixed form and permanent stability of water vapor, indicating a liquid exterior

or thin crust. Next in the scale is the Earth having a cool, thin crust, but exhibiting at and below the surface evidences of having integrated to its present condition through the processes above outlined and at earlier stages in its career of having supported animal and vegetal life in far greater abundance than are now present upon it. Next our attention is invited to Mars which seems to be still farther organized as a world but to have passed the prolific stage of existence, seemingly having lost its permanent water supply and in a large measure its atmosphere but still presumably supporting life, at least vegetal life. Last in the scale comes the Moon, not merely suffering the deprivations of old age, but dead-cold and lifeless.

We reach the conclusion that during this period of integration there is a time, short in duration compared with the life history of the mass, that forms of life appear upon such a body and that their appearance is a result of the process of integration, a necessary corollary; that such result is produced by the operation of natural laws changing antecedent forms of matter.

Let us see if we can find from known results probable antecedents, or forms of matter which acted upon by natural laws will produce the observed results, so that the one is the direct and logical sequence of the other.

The elements of organic matter (disregarding small proportions of such substances as sulphur, phosphorus and iron) are carbon, oxygen, hydrogen and nitrogen, and the various products of these four primaries in their multitudinous combinations one with another, such as sugar and the starchy substances, the fixed oils, fats, gums, resins, albumin, fibrin, casein, etc. It is the difference in the combination of these elements entering into the composition of organic matter which determines whether the substance produced be a crystalloid or a colloid, mineral substance or living tissue. In fact some readily pass from one to the other state. The colloid molecule may be composed of an aggregate of smaller crystalloid molecules having different magnetic and electric relations. Complex are the combinations of these molecules and their chemical modifications as exhibited in the structure of organic matter and particularly in that form constituting animal tissue. Continuous redistribution of matter and motion is going on in these germ seats through the agency of heat and light. What is true of matter in the aggregate is equally true of the smallest factor of the aggregate; matter in the form of germ life obeys the same law that governs matter contained in planetary systems.

Organic matter is then resolvable into molecules of nitrogenous colloidal substance. An aggregate of such molecules, possessors of complex polarities, constitutes protoplasm, the clay from which organisms are moulded. In both vegetal and animal forms there are types of pure protoplasmic life, increasing in mass by the processes of gemmation and spontaneous fission, but cell formation is that most ordinarily met with. In the lower forms of both plant life and animal life the multiplication of cells goes on with the same characteristics. Both exhibit an aggregation of cells in a longitudinal direction, in a lateral direction and in both directions simultaneously; also laterally at intervals, producing a branched structure; also in clusters and groups. The compounding and recompounding of cells, in these various forms, give rise to a great variety of structures, and some of the lower forms of animal life are not well differentiated from similar types of plant life. Structural organisms integrate from homogeneous units to heterogeneous aggregates of units. Without going into the long chain of evidence, which supports the outcome from a scientific standpoint, it would appear with reasonable certainty that the larger and more complex organisms must have succeeded these simple organisms. In fact there can be no other logical conclusion reached viewing the situation inductively, and no other result probable viewing it deductively. In such volatile substances as compose animal tissue integration and disintegration go on side by side with extreme rapidity. Cells aggregate as best suited to supply the wants of existence. Gradually and almost insensibly the physical conditions of a planet change; grouped into periods of ten thousand years each, however, such changes become very pronounced. Change of environment must produce change of structure and functions in animal life which carried on from generation to generation by gradual transitions will evolve species which when compared with previous forms will be new species.

Matter whether it be contained in large aggregates or small, whether in the form of a solar system or animal tissue, in process of integration becomes more and more unlike in its parts. This instability of the homogeneous is as fundamental a law as the law of gravitation. In obedience thereto heterogeneity of species and heterogeneity of parts will result from natural causation; new structures and new functions arise, the result being to evolve a creature of higher order and more complex organism. The condition of homogeneity is a condition of unstable equilibrium. The law is nowhere more forcibly exemplified than in dealing

with universal matter. There is heterogeneity in the distribution of stars in general; also in their distribution with reference to the galaxy; again in their distribution into groups and clusters. There is heterogeneity with respect to the size and radiant energy of stars taken individually; also when taken in groups or clusters, while binary stars exhibit these differences in a marked degree. There is heterogeneity with respect to the motions of stars and the sizes and planes of the orbits of binary stars. The same general features are true with respect to the distribution, size and shapes of nebulæ. The same law is apparent in the solar system. The Sun is nearly a thousand times as great in mass as all the bodies revolving around it; while there is the widest range between the largest planet and the smallest asteroid. The existence of this law is again apparent in the physical condition of the Sun and attendant bodies. There is every degree of density from the gaseous form to the rigid form. There are planets having no satellite and planets with several satellites. No planet or satellite has a perfectly circular orbit; if it had, such a condition could not exist, for external forces would inevitably generate eccentricity, that is to say, a homogeneous relation would lapse into a heterogeneous one. The encrusting of a planet exhibits this change from a comparatively like physical condition to a very unlike physical condition. The same is true with respect to chemical conditions. Gases are disintegrated by heat; hence compounds are thus reduced to their elements. It is not improbable that with the intensity of heat existing at the early stages of encrusting gases now considered by us as elemental are further disintegrated; quite certain it is that in the process of cooling such elements pass into heterogeneous combinations and such combinations become more and more complex.

In a chemical sense there is nothing in a living organism that was not before in existence either in a gaseous, vegetal or mineral form. The elements and their compounds have but passed into a more complex and heterogeneous form. That they must so integrate is to obey natural laws operant throughout all time and all space. Matter is the same everywhere.

The number of stars shown by present visual telescopes is upwards of a hundred millions. Increase of penetrating power increases the number. A considerable number of stars are known to have attendant dark bodies. Sirius is accompanied by a body which glows with a dull, reddish light, rendering it still visible in large telescopes. There is no doubt that this body is far on its way toward becoming a dark body. The same is true of similar

bodies revolving around other stars. In stars of the Algol type the spectroscope shows the existence of dark bodies by proof as undeniable as though actually seen with the eye. We know then that some of the stars are suns for other worlds, and the only question is how many of such there are. It is believed to be the rule that stars generally are so accompanied; that the exception, rather than the rule, is to be found in stars which have no such attendants.

Can reason deduce from known facts any other logical conclusion? The laws governing matter hold good throughout the universe. The physical process that resulted in the condensation of matter to form the star about which we revolve is the same process that brought into their present form of existence other stars, which are suns like in their physical constitution to ours undergoing the same physical changes, and by so doing radiating the same kind of light and heat. Obedience to the same law for gravitation that causes the Earth to revolve about the Sun causes the attendant of Sirius and the attendant of Algol to revolve about their respective primaries. It is unreasonable and illogical to say that matter operated upon by a universal law will produce results that are substantially different. Differences there may be in detail, and probably the universe exhibits a vast variety of such differences, but the general result must be the same. Such general result is the formation of a central sun, the core of the gravitating mass, with earlier formed and smaller bodies, disrupted from such swirling mass, left behind to revolve in elliptical orbits around him. There were eight planetary bodies born of the nebulous mass whose core formed our Sun. Assuming for the average of all other suns visible in the universe but one dark body each, and the result will be to people space with a hundred million other planets. It is equally unreasonable and illogical to say that not one of that mighty array, in the process of its physical development, has produced a single instance of germ life. Let us rather nourish the belief, the hope, that there are other eyes than ours to view the splendors of this universe, other intellects to grapple with its profound problems, other hearts to pulsate and joy under the kindly influences of love.

NEW YORK,
Nov. 1, 1903.

THE AURORAL PHENOMENON OF AUGUST 21, 1903.

WALTER M. MITCHELL.

For Popular Astronomy.

In the November number of Popular Astronomy, Rev. Frederick Campbell describes an auroral phenomenon which seems to be rather unusual in this latitude. The phenomenon was also seen by Professor C. A. Young at Hanover, N. H. Its spectrum as seen by Professor Young was of the auroral type.

The writer was spending some weeks of the summer at Seal Harbor, Mt. Dessert Island, Maine, and on the evening of August 21st witnessed the same remarkable aurora. As described by Rev. Campbell the auroral display was manifest as soon as it had become sufficiently dark. The maximum brightness was at about 9:30 o'clock. The aurora appeared in long columns reaching in some cases nearly to the zenith. The central portion of the display was decidedly to the east of the north point, being in the neighborhood of Capella which was then rising over some hills. In the northwest there was very little display at all.

In parts the aurora was very brilliant, in fact so brilliant as to cast a very perceptible shadow. The brightness was not fixed however, one portion brightening up and another fading. It had the appearance as if a nearly vertical ray of light (from a search light), were moved along very rapidly, changing sometimes twenty degrees in azimuth in as many seconds. The color of the aurora seen at Seal Harbor was a distinct yellowish green; that seen by Rev. Campbell in the Adirondacks was white.

The writer was called away at about 9 o'clock and did not return until 9:30, when the entire aspect had changed, great columns and streamers were flashing up to the zenith from the northeastern horizon resembling very much the pipes of a gigantic organ. Across the sky slightly south of the zenith, from the southeastern horizon to the western horizon extended the archway of light seen by Rev. Campbell. This was not seen before and the writer has no idea of its manner of formation, whether all at once or advancing from one part of the sky to another. It was entirely different in color from the aurora proper, being pure white while the aurora as before stated was yellowish green. It was perhaps slightly brighter than the Milky Way, although the portions between the apex of the arch and Jupiter, and near the western horizon were considerably brighter than the rest. The width of the arch was about three or four degrees. The entire

aspect was of a series of columns perpendicular with the horizon from five to eight degrees in length, one column commencing before another had finished.

The position of the arch in the sky was exactly the same as that given by Rev. Campbell. The light was absolutely steady, did not wave and flash as did the aurora proper.

The whole display was brightest at about 9:30 o'clock. By 11:00 there was nothing but a glow in the northeast; the brightest portions of the arch still remained, but much fainter, the rest had faded out entirely. The next morning the writer learned that between 11:30 and 12 o'clock the aurora had become brighter, but whether the peculiar arch had followed suit it was impossible to find out.

The following facts are to be noted in connection with the whole phenomenon:

The witnessing of the aurora at three different points rather widely separated shows that it was not a local phenomenon. This arch of light was not a local phenomenon in the Adirondacks, but was also seen distinctly on the coast of Maine. As the positions of the arch as seen by Rev. Campbell and by the writer agree very closely it was evidently at a considerable distance above the surface of the Earth.

The arch was altogether an auroral phenomenon since it appeared with the aurora, its spectrum seen by Professor Young at Hanover was that of an aurora, was brightest when the aurora itself was brightest, and behaved in a manner very similar to that of the aurora.

The auroral arch was so situated that the central portion of the aurora along the northeastern horizon coincided with its pole.

PRINCETON, N. J.,
Nov. 2, 1903.

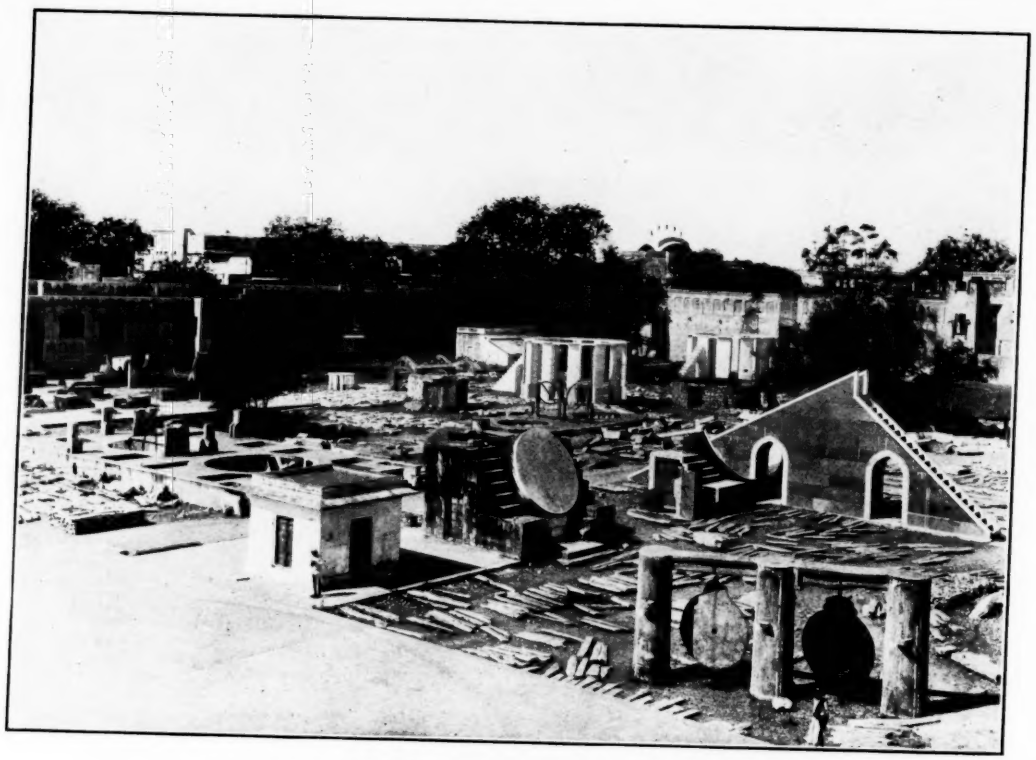
THE OBSERVATORY AT JEYPORE, INDIA.

W. W. PAYNE.

FOR POPULAR ASTRONOMY.

Through the kindness of Miss Etta Moulton, graduate of Carleton College, now missionary to India, we are able to give a fine photographic view of one of the old Observatories in India. The brief description of this old Observatory is by Miss Moulton, and it is copied almost exactly in her own language.

PLATE XIV



AN OLD OBSERVATORY AT JEYPON, INDIA.

The Observatory at Jeypore was built by the celebrated royal astronomer, Jey Sing. It is not under cover. The instruments have been allowed to go much out of repair, and many of them are now quite useless, it being impossible even to guess what purpose they served in the wonderfully accurate observations and calculations of their inventor; but dials, gnomons, quadrants, etc., still remain of great interest to astronomers.

The buildings were erected by Jey Sing II, Rajah of Jeypore, in 1137 A. H., or 1724 A. D. He was an engineer, mathematician, and an astronomer. He constructed on his own plan Observatories at Jeypore, Benares, Ujjain, Delhi and Muttra.

Jey Sing was chosen by Mahammad Shah to reform the calendar. From his astronomical observations tables were constructed which were more correct than those of De la Hire.

One instrument in the picture is the mural quadrant. It is a wall eleven feet high, and nine feet, one and one-quarter inches broad, in the plane of the meridian; by this means are ascertained the Sun's altitude and zenith distance and its greatest declination, and the latitude of the place. There are two large circles. one of stone and the other of cement, and a stone square, used, perhaps, for ascertaining the shadow of the gnomon, and the measurememt of the azimuth. Next the Yantracamant will be seen the wall of which is thirty-six feet long and four and one-half feet broad, and is set in the plane of the meridian. One end is six feet, four and one-half inches high, and the other twenty, two feet, three and one-half inches in height; and it slopes gradually up, so as to point to the North Pole. There are also a double mural quadrant, an equatorial circle of stone, a chakroyantra, between two walls, (used in finding the declination of a planet or star), and a Digansayantra, to find the azimuth of a planet or star.

These Observatories of India built in the beginning of the eighteenth century, if the dates given above are correct, as already said, are of interest to astronomy, because they give definite ideas how the practical side of the science was then being developed. If we could get more information about the way in the work on its practical side was conducted, and a connected account of its history and progress back to the antiquity of the two other civilizations of Egypt and Babylonia, we would have a history that would probably clear up some of the uncertain things that still linger in the modern history of this noble science.

But if we had all this, I suppose we would still wish as eagerly to go back still earlier, and find out if possible, which contributions

would come to us from those very ancient civilizations of the regions we now call India and China. There is hope that some day this connected history of astronomy will be written in full.

STAR DUST,—A DISCUSSION.

J. K. McBROOM.

FOR POPULAR ASTRONOMY.

I believe the author of "Star Dust" in your November issue loses sight of some important points. It is of course true that vast kinetic energy is involved in the movement of worlds in space, and the collision of two such bodies would develop force enough to dissipate the matter into very tenuous nebular condition, the mass in turn condensing, throwing out in the process the heat evolved by the collision and expansion. But assuming that the body had once been very hot and had cooled before the collision, it is not true, as implied in that article, that the heat thus lost before collision had been only transformed into kinetic energy and still retained in that form in the body. The matter had as great a mass and as great a velocity, therefore as much kinetic energy, while still at its greatest heat as after it had become "dead" and cold; and it had *besides*, a vast amount of radiant energy, (*heat*), which it *dissipated*, not transformed, in the process of condensation. This radiation and dissipation of heat has nothing whatever to do with the movement of the body through space; it would be as great if the body stood still, and no greater if its velocity doubled. Nor is there, so far as we know, anything to change the velocity, nor any reason to suspect any change in the velocity, of a wanderer in space; therefore it does not change its kinetic energy at all, even in coincidence with the process of cooling and condensing. The body does not accumulate kinetic energy as it travels, and if it has a uniform velocity,—as we assume that it does have,—it would develop as much heat by collision today as it would a million years hence, though during that interval it would lose into space, in condensing and cooling, much of its radiant energy, if it had any to start with.

Take the Sun as an example. It is in motion at say ten miles a second, toward the constellation of Lyra, taking the planets along; but the heat it radiates is caused, not by this motion but by its particles falling toward the center, producing condensation and contraction of diameter of about 300 feet per year. Now imagine a hollow sphere with the Sun at the center and a ra-

dius equal to the distance from Earth to Sun. Set the Earth in the surface of this sphere; it would occupy about 1/2,200,000,000 of the area and would therefore intercept and absorb about 1/2,200,000,000 of the heat radiated by the Sun. It is inconceivable that all the rest of the heat thus radiated is caught by other heavenly bodies scattered in space. All but a minute fraction of that heat must be forever *lost* in the vast voids of the universe, and no collision of the Sun with another heavenly body could ever recover it.

Another point: Such a collision in space could evolve heat or other form of energy only by *stopping the motion*, or greatly retarding it, and we know no way by which this lost velocity would be regained. There would still be motion, molar and molecular, within the mass of course, and perhaps rotation, but the mass as a whole could not regain its former velocity. Its kinetic energy has been transformed into heat or expended in dissipating the matter into the nebulous condition; and as the mass now cools and recondenses, it radiates this energy into space and loses it. Then what? Manifestly its kinetic energy, first transformed, then dissipated, is gone forever; nor has the mass, in itself, the power of developing more. True, another body may crash into it and drive it again into the nebulous condition, but it would thus acquire new life only by taking it from the second body, the latter thus losing, the more rapidly, its own. But in any case, by far the greater amount of radiated energy is lost.

Nor does it seem probable that the temporary stars are Suns, resurrected or new born by stellar cataclysm. They fade too rapidly. Astronomy has recorded no sensible diminution in the brightness of any of the fixed stars,—except the few variables,—or even of the planets, during all the centuries of astronomical research; yet a new star sometimes fades through several magnitudes in a few days.

Again, whatever the method of resurrection of dead worlds, we can hardly think the living and the dead indiscriminately involved in the same process, as would be the case if collision were that process.

It is a wide-spread popular fallacy, but absolute fallacy nevertheless, that "death is the forerunner of new life in every form of matter." Death is *never* "the forerunner of new life." New life always springs from the old, but always *before the death of the old*, and while that old is at its best and strongest. Life may feed on death, but never spring from it. And yet, reasoning from analogy that seems to be complete and perfect within the little

region of our own petty knowledge and experience, we believe that even in the case of stars and Suns, there must be a "law of life" as well as a law of death; birth and growth as well as decay; but astronomy is not yet able to fathom the mystery. Planets and Sun and stars are radiating their heat and their life away into the inconceivably vast abysses of space. Collision may produce temporary revival,—not resurrection,—but it can only postpone, not prevent, the inevitable end, when the worlds may still wander through infinite space, but they will be dark, dead, cold. The astronomer's vision has not yet pierced the mists that overhang and lie beyond that mighty graveyard of creation.

ELGIN, Minn., Nov. 19th, 1903.

MINOR PLANETS AND THEIR NAMES.

The discovery of the minor planets, the computing of their orbits, and the naming of them have been an interesting branch of astronomy during all the nineteenth century. An account of some phases of this work recently appeared in a very readable, popular article, recently published by Professor J. A. Brashear, in the *Pittsburgh Dispatch* (November 1), extracts from which are given below:

On the night of January 1, 1801, the Sicilian astronomer, Piazzi, discovered a small planet revolving between the orbits of Mars and Jupiter, but before its position could be determined it was lost in the rays of the rising Sun; that is, the twilight obliterated the light of the planet.

This discovery created an intense interest among astronomers, and half a dozen German observers formed an association for the purpose of searching for this and other planets that might be located in the zone between Mars and Jupiter. The great mathematician, Gauss, succeeded in determining the approximate position of the lost planet from the meager data furnished by Piazzi, and in the following November the planet was re-discovered, having passed through nearly one-sixth of the orbit in the interval. Three months later Olbers of Bremen discovered another planet having very nearly the same orbit and period of revolution around the Sun. Shortly afterward two more were discovered farther out toward Jupiter. The new planets were named Ceres, Pallas, Juno and Vesta, in the order of discovery.

Several names have been used to designate these celestial bodies: Asteroids, star-like—planetoids, planet-like—minor planets,

but they are now usually called planets, as they have all the characteristics of the larger planetary bodies. Astronomers began to make systematic observations for other small planets in the great gap between Mars and Jupiter, for it was the common belief that a very large planet once revolved in this gap which had been burst asunder by some great cataclysm and these small bodies were the disintegrated particles of the greater body.

In the interval between 1807 and 1850 nine new planets were located. They were named by the discoverers Astrea, Hebe, Iris, Flora, Metia, Hygeia, Parthenope, Victoria and Irene.

The old methods of research were very laborious, because the star charts then available were very imperfect and incomplete, and when one of these star-like bodies was found, its planetary character could only be determind by a number of observations to detect motion. But astronomers were diligently at work charting the constellations. Night after night the stars were compared with the heavens to see if any object, not on the chart, was in evidence. Whenever a faint, star-like object was found to be in motion, it was hailed as a new planet, observed with diligence, enchained in the toils of mathematics and finally imprisoned in the astronomers' note book.

Many new bodies were discovered by this method of diligent observation, kept up, night after night, through the years, until the astronomical photographic camera was turned toward the zone of the heavens where these wanderers are travelling and the work of the patient observer came to an end. However, most careful and critical measures of the motion, place of the orbit and inclination of each newly discovered planet had still to be made, so that the astronomer would be able at once to differentiate the newly found planets from those already discovered.

The first discovery of a minor planet in America was made by Ferguson of Washington, in 1859, which was given the pretty name Virginia. Professor Peters of Clinton, N. Y., and Professor Watson of Ann Arbor, Mich., have been the most prolific discoverers in America. Peters captured 46, and Watson 26 new planets between the years 1861 and 1889. Dr. Max Wolf, the eminent astronomer of Heidelberg, Germany, was the first to take up the study of the "asteroid zone" by astronomical photography, and after securing a six-inch camera lens which had been used for portraiture, he had the gratification of discovering 17 new planets in less than two years, one of which he named after his native city of Heidelberg.

During the session of the International Astronomical congress

in Chicago at the time of the Columbian exposition, Dr. Wolf presented one of these new planets to the American astronomers for naming. It was proposed to call it Columbia, but Charlois, of Nice, had anticipated the wishes of our astronomers by giving the name to a planet discovered by him only a few months previous. The name Chicago was finally selected, in honor of the place where the congress was held.

Only two other cities have been thus honored; namely, Heidelberg and Allegheny.

Dr. Wolf's splendid work had already received recognition in America, and, as his instrumental equipment was not what it should be, Miss Catherine Bruce, of New York, the great friend of American astronomers, presented Dr. Wolf with the means to secure the largest and best photographic telescope that could be made for his especial research in the domain of planet and nebula photography.

In searching for minor planets within the zone in which their orbits are located, the camera is accurately adjusted on a star which can readily be followed by an attached visual telescope. The delicate clockwork keeps this guiding telescope fixed upon the star, although the observer must frequently touch his independent motion screws so as to keep the star accurately centered from three to four hours on the delicate spider lines of his telescope while the stars and planets, if any, are making their impression upon the photographic plate.

When the picture is developed the stellar images show themselves as small circular dots, but if a planet was in the photographic field during the exposure its image would be that of a very short line or trail about one-twentieth of an inch long, because it has an average movement through space of a little less than half the diameter of the Moon in 24 hours, while the stars remain practically stationary. This tiny trail is the clue to a new planet, or perhaps one already discovered. But so small are these trails that it is sometimes very difficult to determine whether they are photographic defects, or trails made by minor planets, so that a second or even a third photograph has to be taken to make assurance doubly sure. Dr. Wolf conceived the excellent plan of making a double comera, so that when a trail is found on the two plates, exposed at the same time and in the same part of the sky, and these trails found exactly in the same relation to the stars around them, the certainty of their being produced by some moving celestial object is established beyond doubt.

The great double camera constructed for Dr. Wolf is made up

of eight lenses of 16 inches diameter, and each camera has a focal length of 80 inches. In their tubes they weigh nearly 1,000 pounds, yet they must move with the precision of the stars, without a jar or tremor in doing their wonderful work. More than 50 new planets have been discovered with these large astronomical cameras, since their completion in 1900, five having made their record on one set of plates after about three hours' exposure. The first planet photographed with the new cameras was named by Dr. Wolf in honor of the city of Allegheny, and this pretty little planet of the twelfth magnitude, registered in astronomical annals as Alleghenia, is now sailing in its course around the Sun, unmindful of the political and other troubles that are worrying the good people of the city for which it was named.

On the night of April 29, 1902, Dr. Wolf discovered a new planet of the 12.5 magnitude in the constellation of Libra. It was carefully studied by trained observers and its position noted among the stars as it moved along in its orbit. The German mathematician, Dr. Berberich, calculated the "elements" of the planet, which, according to the adopted system, was charted as No. 484 HX—1902. From the data given by Dr. Berberich, the mean distance of this planet from the Sun is 248,850,000 miles, nearly three times that of the Earth. By comparing its orbit with those of several other planets, the writer finds it is close to that of Juno, one of the first discovered; still closer to Proserpina, and very nearly identical with that of Cassandra. Its period of revolution around the Sun is 1,600 days, or four years, four months and twenty days. The inclination of its orbit to that of the Earth is 12½ degrees. In a recent letter from the discoverer to the writer Dr. Wolf "presents" him with the honor of naming this planet. Desiring to share this honor with the good people of this great city, he proposed the name "Pittsburghia," which has been accepted by Dr. Wolf, and henceforth planet No. 484 will be recorded in astronomical annals with the name of our city as it is engraved upon its great seal, except that the Greek suffix has been attached to the last syllable to make the name more euphonious, as has been the custom in all names permitting this ending.

Some time in the far-distant future our great city may lie silent and dead, as Mycenæ or Pompeii, but her name, now recorded in the skies, will be remembered as long as the beautiful science of astronomy has its votaries on Old Mother Earth.

ASTRONOMY IN THE HIGH SCHOOL.

MARY E. BYRD.

For Popular Astronomy.

The late articles on "The Small Telescope in the High School" by the senior editor of Popular Astronomy are very suggestive. They have led me to formulate the following short confession of astronomical faith as regards practical teaching in elementary astronomy.

In my judgment we who are teachers of beginners should hold fast to two ideals. We should lead and inspire our students to be watchers of the heavens, friends and lovers of the stars. We should maintain symmetry and proportion in dealing with the wealth of material offered by the oldest of the sciences.

As a guide in realizing these ideals, we may well take the work of astronomers in the large, making, however, no attempt to use their fine tools or obtain their high degree of accuracy.

Now, astronomers study the heavens with two widely different objects in view. The "bright orbs" overhead, like powerful genii of the lamp, are invoked to further simple human undertakings. The stars help us to find latitude, longitude and time. On the other hand the whole heavenly array, Sun, Moon, stars, nebulæ, planets, comets and meteors are watched and studied not that they may help us, but that we may find out about them.

A glance at the different investigations connected with these two main objects will show that the fundamental problems of the astronomer have usually their humble counterpart within reach of our students. They cannot regulate standard clocks to a small fraction of a second, nor make definitive determinations of latitude. But they can compare their watches with a sun-dial and from the shadow of a gnomon find how many degrees it stands north of the equator. They are able to take no part in the cataloguing and charting which fix star-places for use at observatories. But they can become familiar with the constellations and call the bright stars by name. To unravel the tangled web of real and apparent motion, to predict not only the position of bodies in their orbits, but the form and position of the shifting orbits themselves,—these things are beyond the reach of beginners. But they can measure the Sun's altitude at noon and its azimuth at setting, and track the course of the planets as they wind in and out among the constellations. While it is a thing too hard for them even to grasp the meaning of the methods em-

ployed in astro-physical study at the Lick and Yerkes Observatories, they may watch spots on the Sun, identify lunar markings and note Algol's shifting light.

I should therefore conclude that for substance of doctrine the following list of subjects should stand as fundamental in any scheme for the practical study of elementary astronomy.

1. The Constellations.
2. Diurnal Paths of Sun, Moon and Stars.
3. Paths of Moon and Planets among the Stars.
4. Latitude and Time.
5. Use of Opera-Glass or Small Telescope.

There is a mistaken notion that such a scheme as this is simple and easy. I thought so once myself. Enthusiasm and love of one's work are powerful enchanters. And yet, as I look back calmly and coolly on my painstaking efforts for more than a score of years to work this course out with real boys and girls in High School, Academy and College, I am ready to recant. The work involved is about the hardest that a teacher can undertake. None but those who have held star-watches on many nights of many years know how difficult it is to co-ordinate time, phenomena and pupil. No cunning mathematical formula in the theory of probabilities will enable us to predict for any given evening the actual configuration between stars, students and clouds. We are practically denied both work-shop and tools. In this present dark age of elementary astronomical teaching, High School instructors might about as well demand to have the stars themselves brought down to the school-room as to ask for an astronomical laboratory. They usually obtain only by toil of soul and sorrow of heart so much as a north and south line and a place to see the sky. Ah, if so many trees did not grow in the wrong places, if only a meridian line could be bought and set up (or rather down) as telescopes are!

It falls to our lot, also, to contend with foes within as well as without. Our very liberties bring temptation, since as yet there is no core of instruction recognized everywhere as essential, it is, on the one hand, only too easy to neglect continuity and detail and lead our students into by-paths here and there, where things curious rather than fundamental take their time and attention. Especially is this so, if we have worked out a neat method of reduction or devised some little instrument that is to be brought into use. On the other hand, we are beset by the temptation to turn away from the little, simple things and by a process of forcing, carry our students through what we are pleased to call real

astronomical work. The thing sounds well, looks well perhaps in print; but can be attained only by ignoring proportion in our teaching, neglecting the foundations of astronomical knowledge, and leaving students in the end fitted to do well neither elementary nor advaneed work.

It is seldom the part of wisdom to shut our eyes to real dangers in the path before us. But from my own point of view, the conclusion of the whole matter is this. It were better to fail in teaching elementary astronomy according to practical methods rather than win apparent success in the old ways, long since discarded in other sciences.

SMITH COLLEGE OBSERVATORY,
NORTHAMPTON, Mass.

MAGNETIC STORMS, AURORÆ AND SOLAR PHENOMENA.

WILLIAM J. S. LOCKYER.

The attention of the whole civilized world has this year been directed to the importance of finding a connection between terrestrial and solar variations, but the phenomena recorded last Saturday in the nature of a great magnetic storm and a brilliant aurora borealis have perhaps brought home to many the desirability of pursuing such investigations which may help us to be forewarned, and therefore forearmed.

The enormous development of the telegraph, telephone, cable, and other applications of electricity since the date of the last great magnetic storm has caused the disturbance to be more generally observed than was previously perhaps the case.

Practically the world's whole telegraph system was upset, and information from this country, France, the United States and other lands, shows that for several hours communication was almost completely interrupted.

According to the *Daily Mail* the London telegraphic department characterized the storm as the most extraordinary ever experienced. Messages dispatched on Saturday from Russia, Spain, Switzerland, France, Germany, Belgium, and other countries, which would ordinarily have been received an hour or less after transmission, were still slowly coming through on Sunday morning. Mr. Gavey, the electrician-in-chief to the Post Office, in an interview with a *St. James's Gazette* representative, said the storm was the most severe that had been experienced for the last twelve years. The effects of it were first felt at St. Martin's-le-

Grand at 6:45 A. M. on Saturday, and they continued until five in the afternoon. It was eight o'clock before the storm had completely disappeared.

The New York correspondent of the *Daily Telegraph* states that the magnetic disturbance was felt practically everywhere in the United States, affecting the great cable companies for a time, while the telegraph wires in all directions from Chicago felt the effect; the long distance telephones were similarly troubled. The disturbance lasted eight hours, and at its climax "there were 675 volts of electricity—enough to kill a man—in the wires, without any batteries being connected to them." During the magnetic storm which occurred in 1871 the Eastern Telegraph Company showed that there was an Earth current of 170 volts on their Suez-Aden line.

The *Times* correspondent in Paris states that according to a Press communication from the French Under-Secretary of State for Posts and Telegraphs the magnetic phenomenon extended in all directions, but with somewhat less intensity towards the northwest; the telegraph office was from nine o'clock in the morning deprived of communication with the greater part of the French towns and the adjoining districts. It was subsequently also cut off from communication with America, Spain, Portugal, Italy, Algeria, Tunis, and places beyond those countries. At 4:40 P. M. communication was re-established; it was again interrupted at 5:30 P. M., but a little after sunset almost all communications were found to be restored.

It is interesting to note that the effect of a magnetic storm on a telegraphic system may be modified in two, if not more, ways, and this was done in the case of our own Post Office. One method, as stated by Mr. Gavey, is to join two wires, thus forming a loop, and in this way eliminate the Earth from the circuit. The other means is to employ condensers; these, when connected up with the circuit, stop a continuous current such as is set up by magnetic disturbances.

In several regions the magnetic disturbance was accompanied by a display of the aurora. In New York on Saturday morning the northern sky was described as "a dazzling display of light and color;" it was first seen in the city at two o'clock, but faded away at four. In Ireland and Scotland during Saturday evening the aurora was also observed.

A message from the Sydney correspondent of the *Times* states that a beautiful Aurora Australis was seen there on Saturday night, the streamers reaching nearly to the zenith.

Earthquakes also seem to have been recorded as well. On Friday and Saturday two undulating shocks were felt at Benevento and Avellino, in Italy, the first lasting two seconds, and the other a minute.

In Essex several distinct earthquake shocks were felt at Saffron Walden. At midnight on Saturday one shock is stated to have lasted five minutes. These were repeated at 5:50 and 9:30 on Sunday morning. At Debenham, four miles distant, shocks were felt on Monday sufficiently strong to cause small articles to fall to the ground.

Tuesday's *Daily Mail* publishes a telegram from Simla (dated November 2) in which it is stated that terrible earthquakes occurred at Turshiz, near Turbatihaideri, in Persia. Unfortunately, the time of occurrence was not mentioned, and up to the moment of writing (Tuesday evening) the news has not been corroborated.

In a communication to the writer from Stonyhurst, Father Cortie writes: "We had a magnificent magnetic storm on Saturday and Sunday, the biggest ever recorded here. The declination magnet swung through 2° 46′. The spot of light for the horizontal force travelled several times right off the pages on the drum."

From the above brief summary of the information to hand it will be gathered that we have experienced a storm of quite considerable magnitude, not perhaps the worst that has ever been recorded, but at any rate a "great" disturbance.

Two important questions now arise. What is the cause of these sudden magnetic phenomena? Can they be predicted?

The first of these questions is one which is answered differently by different investigators. Some think that there exists a common cause external to the Sun, while others are agreed that the storms originate from the Sun itself; there are also many who go more into detail and are inclined to favor the view that they are caused by sun-spots.

In the last mentioned case then it is natural to conclude that when there is a large spot we should experience a magnetic storm, and when there are no spots storms should be absent. This, however, is not the case. The true explanation must account for the three possibilities of the appearance of these storms.

(1). A large spot *with accompanying* magnetic disturbance and auroræ.

(2). A larger spot *with no accompanying* magnetic disturbance and auroræ.

(3). No great apparent solar activity, but magnetic disturbance and auroræ.

Since sun-spots cannot be held to satisfy these necessary conditions, are there other solar disturbances which can be utilized? Yes, there are the prominences which were first seen projecting beyond the dark limb of the Moon during total solar eclipses. Up to the year 1868 these were the only opportunities when such solar appendages could be observed, but during that year a method was discovered by Sir Norman Lockyer and Dr. Janssen by which they could be seen on the Sun's limb at any time without the necessity of waiting for these brief opportunities. It was not, however, until the year 1870 that regular observations of the limb of the Sun showing these indications of solar activity were commenced, but, thanks to the magnificent work of Respighi, Tacchini, Ricco, and Mascari, we have practically a continuous record of them up to the present time.

The question then arises, are these prominences in any way related to the occurrence of magnetic storms? Before answering this, a few preliminary remarks may be made.

In the first place the number of spots on the Sun is nearly always insignificant compared to the number of prominences. Prominences are, therefore, of greater relative importance than spots.

While sun-spots are restricted to practically a narrow zone ($\pm 5°$ to $\pm 35°$) on each side of the solar equator, prominences can and do occur all over the Sun's disc. Again, the general trend of the spot circulation is from the higher to the lower latitude, while in the case of prominence the reverse happens. In some years we have a great number of prominences near the solar equator, while in other years they are observed also in great numbers near the solar poles. A glance at some curves recently published in this Journal (vol. lxviii. p. 257, July 16) will show not only the general drift of prominence activity, but the epochs when the prominences were present near the polar regions of the Sun. The years in which they attain these high latitudes are not numerous; they are (first observations made in 1870) 1870, 1871, 1881, 1882, 1892, 1893, and 1894. Mr. William Ellis, who has made a special study of magnetic disturbances, has tabulated the number of days of "great" disturbances, that is, those recorded at Greenwich above a certain standard. These are utilized to form the following table:

Date.	Number of years.	Number of days of "great" magnetic disturbances.	Average per year.
1870-1872 ...	3 ...	16 ...	5.33
1873-1880 ...	8	2 ...	0.25
1881-1882 ...	3 ...	10 ...	3.33
1883-1891 ...	9 ...	1 ...	0.11
1892-1894 ...	3 ...	7 ...	2.33
1895-1900 ...	6 ...	2 ...	0.33

Another and perhaps more striking way of showing the coincidence of the epochs of the occurrence of days of magnetic disturbances and polar prominences is illustrated in a figure (see *Nature*, February 19, vol. lxvii.)

The continuous and broken vertical lines indicate the epochs of maxima and minima sun-spots, showing that the former tend to occur later than the peaks of the magnetic curves. In this diagram Respighi's observations of polar prominences made during the years 1870 and 1871 are not included, but their mean latitudes for each hemisphere during these years were $\pm$ 70°.

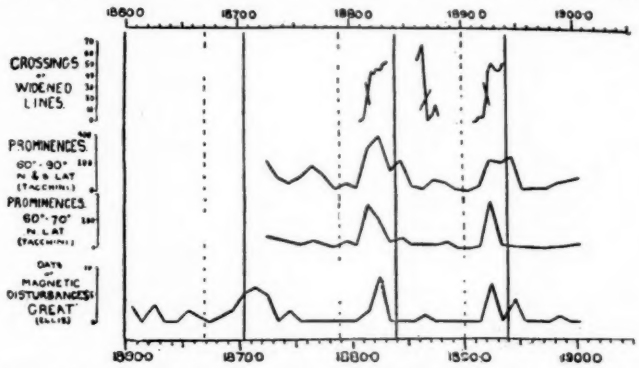
It will thus be seen from the above that the occurrence of polar prominences is closely associated, at any rate in time, with great magnetic storms, and, therefore, with auroræ, which nearly always accompany them. Further, prominences fulfil the three conditions mentioned previously in this article, for they can occur when there are spots and also when there are none.

One argument used against the prominence theory is that the polar prominences are "quiet" prominences and therefore are not likely or are possibly not capable of producing such large terrestrial effects. The critic may, however, have forgotten to consider the possible and natural conclusion that the appearance of prominences in high latitudes may at least be simply an indication of greater action occuring nearer the equatorial regions with consequent greater extension of the disturbed region towards the polar zones.

That the polar regions of the Sun are sometimes greatly disturbed is again emphasized by the presence of enormous streamers that are seen in those regions during some total solar eclipses. Further, these polar streamers are observed only at those times when the prominences approach high latitudes. Here again we have good cause to doubt the inability of these polar prominences as disturbing agents. Even if the prominences be not conceded to be the initial cause of magnetic storms, their gradual changes of position towards the solar poles may afford a valuable means of forecasting the epochs of magnetic disturbances.

From the facts before us let us consider the question of forecasting the years in which magnetic storms should occur. If the

reader will glance at the figure accompanying this article and continue the curves on the assumption that the last sun-spot minimum occurred in 1901.5 and the next maximum in 1905, he



Comparison showing days of "great" magnetic disturbance, polar prominences and crossings of widened lines. (The continuous and broken vertical lines indicate the epochs of sun-spot maxima and minima respectively.)

will most probably make a maximum fall between these two dates, but somewhat nearer the latter; in fact the maximum would have been placed in the middle of the year 1903. It will be noticed, however, that at the sun-spot maximum of 1870, the disturbance curve reaches a maximum a year after 1870. A recent investigation has indicated that all sun-spot cycles are not alike in intensity, and that the cycle commencing in 1901 may probably correspond to that which commenced in 1867. If, therefore, the coming sun-spot maximum should attain the same dimensions as that reached in 1870, it seems quite possible that the magnetic disturbance curve for the present cycle should correspond to that portion commencing about 1867. If this be so, then not only should polar prominences be recorded from the years 1903 to 1906 or 1907, but during these years "great" magnetic disturbance will be liable to occur. As shown in the previous table, no less than 16 of Ellis's "great" magnetic storms occurred between 1870 and 1872; also two occurred in 1869 and one in 1868, so that if we consider the present year to correspond to 1868 there is much in store for us. It may be mentioned also that since the years 1899 and 1900 the prominences have exhibited the tendency to attain high latitudes, so that there seems every reason to suppose that magnetic storms and auroræ may be experienced during the course of the next three or four years, after which there will be a cessation for about ten or eleven years.—From *Nature*, November 5, 1903.

PROSPER HENRY.

O. CALLANDREAU.*

FOR POPULAR ASTRONOMY.

Born December 10, 1849, at Nancy, Prosper Henry entered the Observatory of Paris March 1st, 1865, as an assistant in the meteorological service. His brother Paul had already been there for a year previous. From this moment began an intimate collaboration which was to cease only with the death of our colleague, which took place on the 25th of last July.

This death terminates a friendship between two brothers so united that often at the Observatory we saw in them but one person, so to speak; so forgetful were they of giving prominence to their respective merits that it is really impossible to discern what may belong to each one in their common work.

Prosper and Paul Henry were appointed assistant astronomers at the same time, June 3d, 1868. The title of associate astronomer came in 1876; the nomination of Paul was on May 5th, that of Prosper on August 29th. It was in the interval from 1868 to 1876 that the two brothers became conscious of their astronomical vocation. After some attempts at polishing glasses they succeeded with a mirror measuring $0^m.30$; and with this, in their little lodging at Neuilly, by means of a second hand clock, they constructed an ecliptic chart. Delannay, who was then Director of the Observatory, on learning of this did not hesitate to transfer them from the meteorological department to the astronomical; and he entrusted to them, July 1st, 1871, the equatorial instruments in the garden. The discovery of a little planet, Libératrix, followed by thirteen others was the natural result of the making of the ecliptic chart, a work of long duration which Chacornac had begun and which afterwards was to give the idea of an enterprise far more vast, that of the map of the heavens with which the names of the two brothers are associated forever.

Until 1884, as we find from the annual reports of Admiral Mouchez, the execution of the ecliptic chart remained the principal occupation of the two brothers; the work became more and more difficult as they approached the Milky Way, yet a number of observations considered delicate were obtained, like those of the satellites of Uranus and of Neptune; at each opposition sketches on a large scale of the planets Mars, Jupiter, Saturn and Uranus were collected with care. In 1882, the observation of

* Astronomer in the Observatory of Paris.

the transit of Venus on the mountain Pic du Midi, on the 6th of December in a very severe season, exposed them to the greatest dangers; scarcely had they reached this high altitude when a violent wind accompanied by a heavy fall of snow rendered all re-provisioning impossible for a number of days and came near having tragic consequences.

It is in his report for 1884 that admiral Mouchez foresees with much confidence, relying on the favorable results obtained by the Messrs. Henry, the solution of the long studied problems of making a chart of the heavens by the aid of photography.

In fact the Messrs. Henry then had recourse to this method for surmounting the difficulties presented by the construction of the ecliptic chart in the neighborhood of the Milky Way. From the very first trials, with an object-glass of 6 inches cut by themselves, they obtained remarkable negatives of several groups of stars.

We ascertain especially in the heliogravure reproduction of the photographic plate of the cluster of Perseus obtained October 10th, 1884, that the images of stars up to the 12 and 13th magnitude are shown with extreme clearness. The dots on the plate showed such great preciseness that more than one astronomer was at first skeptical. Scholars from foreign countries came to Paris to examine the plates with their own eyes. The success depended principally, as one may imagine, on the rare perfection of the optical work of the object glass. Admiral Mouchez then decided on the immediate construction of the photographic equatorial with an aperture of $0^m.34$ and a focal distance of $3^m.40$, which became the type of the instruments chosen by the first International Astrographic Congress meeting three years later in 1887, at the Observatory at Paris.

In this short space of time, from 1884 to 1887, the Messrs. Henry had in fact succeeded in convincing the scholars,—refractory sometimes against the novelty—of the value of these new processes for physical astronomy as well as for the description of the sky, witness, their admirable plate of the Pleiades and their beautiful photographs of stellar apparitions. The measuring apparatus of the plates, constructed by M. Gautier under their instructions, finally proved to all the high degree of precision of the photographic method. Numerous theoretical and experimental researches accomplished by the Messrs. Henry have contributed to render the new processes of exploring the sky more efficacious and more rigorous.

This is not the place to enter more into the details of the great

enterprise which, today, is well under way in its execution, as much for the work of the catalogue as for the chart properly speaking. But we must acknowledge that the very honorable advance made by the Paris Observatory in 1887 had as its cause the ingenious and energetic activity of our two colleagues, and especially their perfect understanding of optics, which has enabled them to accomplish marvellous things as though but for their amusement.

In France the optical parts of all the great instruments have come from their hands, from the telescope of Toulouse with an aperture of $0^m.80$, for a beginning, to the great telescopes of Nice, Paris and Meudon. Finally, more than half of the photographic object glasses in the whole world, destined for the map of the heavens, are their work.

Such brilliant merits had assured for our two colleagues the high esteem of all the astronomers. Expressions of honorable distinction came in abundance, first of all from foreigners. But the simplicity, which was characteristic of the colleague whom we have lost, remained unchanged. As I see him in my memory nearly thirty years ago when I entered into relations with him, so he was to the last; modest, reserved almost to excess, voluntarily effacing himself on every occasion. Without the Congress of the chart of the heavens one would never have known, so to speak, at the Observatory the solidity and variety of the scientific knowledge which our colleague had gained by his personal efforts, the sureness and keenness of a judgment highly appreciated by the scholars who came to initiate themselves in the practice of astronomical photography.

THE RECENT LARGE SUN-SPOTS.

DAVID E. HADDEN.

For Popular Astronomy.

Following a period of comparative quiescence on the solar surface, or at least freedom from large spots, extending over a period of many months; the great group of October 4-17th, 1903, was a welcome visitor to students of solar phenomena.

Not since the great sun-spot group of September, 1898, which belonged to the old cycle of sun-spot activity, has any disturbance of the first magnitude appeared; the minimum epoch having been passed in 1901, observers were expecting some fine outbursts to occur at any time; especially as the period of maximum

spottedness ought soon to be showing some decided evidence of its approaching activity.

The recent sun-spots received so much attention by the press and public, and the coincident terrestrial electrical and magnetic effects were so marked and widespread, that an account of the disturbance as viewed by the writer through a 4-inch refractor and 8½-inch reflector with polarizing eyepiece may be of interest.

October 4th. At 2:00 P. M. a portion of the group was just appearing at the extreme edge of the southeast limb, in heliographic latitude about 28° south, as two small spots, surrounded by ridges of brilliant faculæ.

October 5th, 1:00 P. M. The group today was fairly well in on the disc, but owing to foreshortening, its true appearance could not well be made out. A small normal spot preceded the main group and was closely followed by the largest member of the disturbance, this consisted of an immense elongated penumbral spot, containing an umbra which apparently extended the entire length, and under high powers had a knotted appearance; following this spot were patches of penumbra and other spots only partly visible, and the entire group was in the midst of an extensive region of bright faculæ.

October 7th, 8:00 A. M. The definition being very poor it was impossible to secure a proper observation this day, but the region closely following the largest spot was a broken mass of penumbral matter interepersed with numerous nuclei.

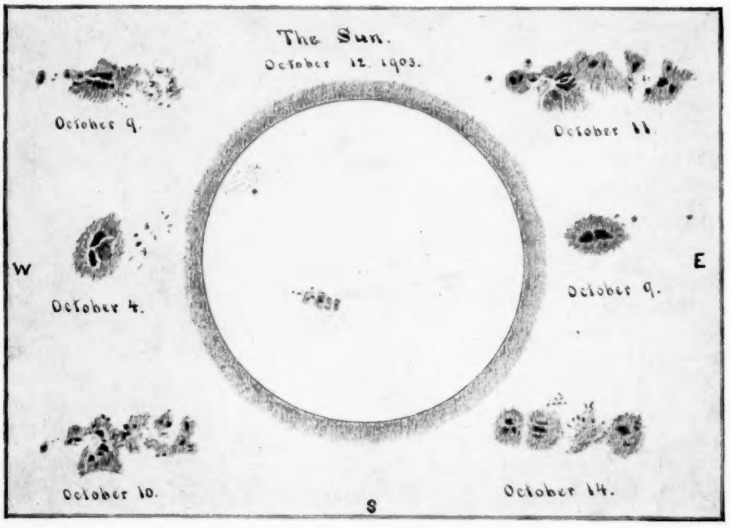
October 8th, 1:30 P. M. The entire group was today well in on the solar disc and was a superb object, its apparent length as measured with a filar micrometer was 231 seconds of arc and width about one-third as much, the object was very conspicuous to the naked eye protected by means of darkened glass. The group was in an active condition, the spectroscope revealing many reversals of the hydrogen lines, and distortion of the $H\alpha$ line toward the red end of the spectrum. the entire group was studded with large and small nuclei in beautiful masses of interlacing penumbræ.

October 9th, 1:30 P. M. The group has changed quite decidedly during the past 24 hours, the larger masses of umbræ have arranged themselves in two somewhat parallel ridges as if the forces at work beneath the photosphere were suddenly being propelled in a westerly direction; the nucleus of the small preceding spot was double this day, and the apparent length of the group had increased to 269″.

October 10th, 1:00 P. M. Remarkable changes have taken place

since yesterday, the group now having a somewhat scorpion-like appearance, the larger preceding portion which yesterday contained the double row of umbræ was entirely changed today, the central part was shattered by some tremendous force and the resulting small nuclei arranged in the form of a semi-circle, the large branching penumbra in the balance of the group was full of small nuclei,—about 40 in all—being counted.

The group was almost on the central meridian and hence extended to its fullest extent, and measured about 300″ in length and 86″ in width embracing an area of over 5,000,000,000 square miles.



The above sketches were made at the eyepiece of the 4-inch telescope, supplemented by sketches made by projecting the Sun's image on a circle about 18 inches in diameter. The enlarged views of the great spot were selected to show the great changes which took place in short intervals of time. The large oval spots at east and west limbs of the central image of the Sun, are very much enlarged proportionally, and indicate the appearances of the smaller spot seen near the west limb, on the dates indicated. Owing to the form of eyepiece used the Sun's image and spots are shown reversed east and west.

October 11th, 2:00 P. M. Remarkable changes have again occurred in the preceding portion, evidence of cyclonic motion being very apparent, large fissures in the umbræ and penumbra indicated the result of the gigantic gaseous, electrical or other forces at work beneath the surface.

October 12th, 8:00 A. M. The main spot is now in two portions and contains about 14 separate large and small penumbral masses and spots and is still a superb group; the fissures noted yesterday have partly filled up and the umbræ are again much changed.

October 13th, 1:00 P. M. The penumbral masses are becoming detached and are in three or four large portions now, evidence that the group has passed the active stage.

October 14th, 8:30 A. M. The group today consists of three large spots, each with many large and small nuclei, and the central portion of the whole group filled with a multitude of small nuclei and dots in tracings of penumbra.

October 16th. It is now nearing the western limb and consequently much foreshortened. It has now assumed the two-spot formation, both members of which are yet large and the region between them filled with numerous small spots.

October 17th, 1:00 P. M. The group is now almost on the limb, a portion of it having already disappeared by solar rotation. An observation at 1:00 P. M. on the following day found its place marked by only small facula and some "spike" prominences.

The great spot made the transit of the disc in about 13½ days, and with the exception of the first few days of its existence on the visible disc, when occasional reversals of the Hα and other lines occurred, very little active spectroscopic disturbance was noted. Bright aurora was observed on the night of the 12th and the return of the disturbed area by rotation at the east limb on October 30th-31st was coincident with auroras and remarkable electro-magnetic Earth currents throughout the Earth's northern hemisphere.

ALTA, Iowa, November 20, 1903.

PLANET NOTES FOR JANUARY.

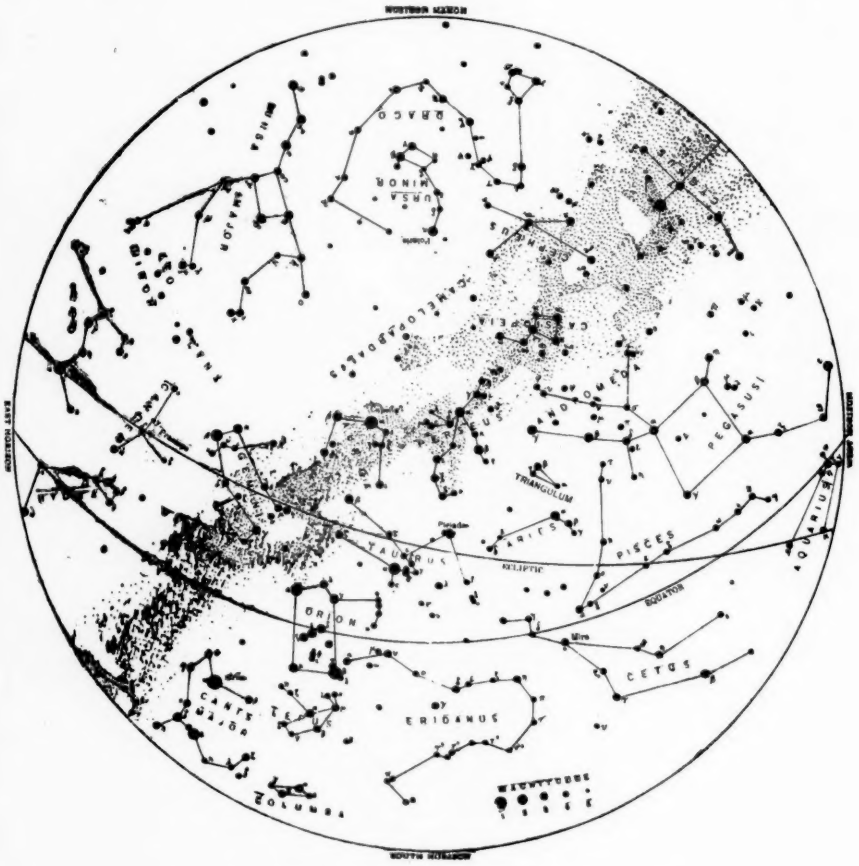
H. C. WILSON.

Mercury will be at greatest elongation, east from the Sun 19° 30′ on the morning of Jan. 1, 1904, and so will be visible as evening star during the first week of the year. It may be seen only a little while each evening about a half hour after sunset. On Jan. 17, at 6 A. M., Central Standard time, Mercury will be in conjunction with the Sun, and about a week or so later the planet will become visible as morning star; to be seen then toward the southeast.

Venus is the brilliant morning star seen toward the southeast after 4 A. M. About two-thirds of Venus' disk is illuminated and the phase will increase to

three-fourths during the month. The planet is passing through the constellation Scorpio.

Mars may be seen low in the southwest soon after sunset but is not in favorable position for observation.



THE CONSTELLATIONS AT 9 P. M. JANUARY 1, 1904.

Jupiter may still be observed in the early evening, being near the meridian at 4 P. M. He is the most brilliant of all the stars seen in the evening sky. In *A. N.* 3908 Mr. A. Stanley Williams expresses the opinion that each of the two equatorial belts of Jupiter varies in redness periodically in a period of about 12 years, and that when the south equatorial belt is at a maximum of redness the north equatorial belt is at minimum, and vice versa. According to his observations the north equatorial belt should be intensely red this year, while the south equatorial belt should be colorless or of a bluish tint.

Saturn is also evening star and may be seen toward the southwest, in Capricorn, early in the evening, but is not in favorable position for observation. He will come into conjunction with the Sun on Feb. 1.

Uranus is morning star just emerging from the solar glare. On Jan. 28 Uranus will be in conjunction with Venus, the former being then nearly 2° north of the latter.

Neptune is near the meridian at 11 P. M. and therefore is in best position for study. He is to be found, with the aid of a good telescope, among the faint stars near μ Geminorum, his course being westward and passing by μ on the 17th. At the time of conjunction Neptune will be just 15′ south of the star. The star μ is of the third magnitude while Neptune is of about the eighth magnitude.

The Moon.

1904	Phases.	Rises. (Central Standard Local Time 13m less.)	Sets. Time at Northfield
		h m	h m
Jan. 2-3	Full Moon	4 41 P. M.	7 48 A. M.
8-9	Last Quarter	11 53 "	11 43 "
17	New Moon	7 27 A. M.	5 24 P. M.
25-26	First Quarter	11 27 "	1 20 A. M.

Occultations Visible at Washington.

Date. 1904.	Star's Name.	Magnitude.	IMMERSION. Washington M. T. h m	IMMERSION. Angle from N pt. °	EMERSION. Washington M. T. h m	EMERSION. Angle from N pt. °	Duration. h m
Jan. 2	26 Geminorum	5.1	6 42	84	7 42	271	1 00
3	1 Cancri	5.9	12 21	90	13 37	295	1 16
5	B.A.C. 3398	6.0	11 32	163	12 11	231	0 39
9	82 Virginis	5.3	14 56	95	16 06	315	1 09
22	W.B. xxiii 1069	6.9	5 44	34	6 56	273	1 12
25	ξ Arietis	5.4	6 25	87	7 48	231	1 23
27	75 Tauri	5.3	14 58	99	15 47	256	0 49
28	111 Tauri	5.2	14 07	148	14 40	217	0 33
31	29 Cancri	5.9	12 29	128	13 39	267	1 10

COMET AND ASTEROID NOTES.

The Orbit of Comet 1900 II.—In *A. J.* 548 Mr. J. M. Poor of the Shattuck Observatory of Dartmouth College gives the results of a definitive determination of the comet 1900 II, which was discovered by Borrelly at Marseilles, July 23, 1900, and independently by Brooks of Geneva, New York, on the same date. The comet was observed was about three months and a rough observation after five months showed it to be very closely in the place predicted with the aid of parabolic elements. Mr. Poor finds the orbit to be hyperbolic, and in this he agrees very closely with the results previously published by Manoel Soares de Mello e Simas. In studying the perturbations of the orbit by the attraction of the planets, during the year previous to the comet's discovery, Mr. Poor finds that the eccentricity was increased during that time and that is not unreasonable to account for this hyperbolic orbit as a result of perturbations.

ELEMENTS OF COMET 1900 II.

Epoch of Osculation, July 29.0, 1900.

$T = 1900$ Aug. 3.199851 Gr. M. T.

$\omega = 12° 25' 40''.55$

$\Omega = 328 \quad 00 \quad 47 \quad .62$ } 1900.0 $\log q = 0.0063951$

$i = 62 \quad 31 \quad 16 \quad .38$ } $\log e = 0.0001430$

Search Ephemeris for Faye's Comet.—In *A. N.* 3913 Mr. Elis Strömgsen extends his search ephemeris for Faye's comet through November and December. The portion for December follows:

	Perihelion May 26.						Perihelion June 3.						Perihelion June 11.					
	R. A.			Decl.			R. A.			Decl.			R. A.			Decl.		
	h	m	s	°	′		h	m	s	°	′		h	m	s	°	′	
Dec. 1	10	01	24	−0	38.1		9	54	16	−0	19.0		9	46	43	+0	01.0	
5	10	03	18	−1	03.9		9	56	05	−0	45.1		9	48	26	−0	25.5	
9	10	04	48	−1	27.4		9	57	29	−1	08.8		9	49	42	−0	49.6	
13	10	05	53	−1	48.5		9	58	26	−1	30.1		9	50	31	−1	11.0	
17	10	06	32	−2	07.0		9	58	57	−1	48.7		9	50	52	−1	29.6	
21	10	06	45	−2	22.7		9	59	01	−2	04.3		9	50	46	−1	45.2	
25	10	06	30	−2	35.4		9	58	38	−2	16.9		9	50	12	−1	57.5	

Ephemeris of Winnecke's Periodic Comet 1903-04.

[Computed by C. Hillebrand. A. N. 3907.]

Berlin Midn. 1903.	R. A. h	m	s	Decl. °	′	″	log *r*.	log Δ.
Nov. 25	14	54	18.36	— 6	33	7.1	0.094136	0.324344
26		57	57.47	6	53	16.9		
27		1	38.61	7	13	27.7		
28		5	21.80	7	33	39.1		
29		9	7.05	7	53	50.7	0.081493	0.316550
30	14	12	54.40	8	14	2.2		
Dec. 1	15	16	43.86	8	34	12.9		
2		20	35.45	8	54	22.3		
3		24	29.20	9	14	29.9	0.068849	0.309128
4		28	25.13	9	34	35.7		
5		32	23.25	9	54	38.4		
6		36	23.57	10	14	37.7		
7		40	26.10	10	34	32.6	0.056289	0.302096
8		44	30.83	10	54	22.8		
9		48	37.80	11	14	7.6		
10		52	47.10	11	33	46.3		
11	15	56	58.65	11	53	18.0	0.043917	0.295577
12	16	1	12.42	12	12	42.7		
13		5	28.43	12	31	59.0		
14		9	46.67	12	51	6.3		
15		14	7.14	13	10	3.8	0.031856	0.289620
16		18	29.85	13	28	50.8		
17		22	54.77	13	47	26.3		
18		27	21.89	14	5	49.6		
19		31	51.19	14	23	59.7	0.020252	0.284296
20		36	22.68	14	41	56.0		
21		40	56.32	14	59	37.4		
22		45	32.07	15	17	3.1		
23		50	9.93	15	34	12.3	0.009267	0.279632
24		54	49.88	15	51	4.1		
25	16	59	31.87	16	7	37.6		
26	17	4	15.84	16	23	51.9		
27		9	1.77	16	39	46.0	9.999087	0.275716
28		13	49.65	16	55	19.2		
29		18	39.38	17	10	30.5		
30		23	30.90	17	25	18.9		
31	17	28	24.13	— 17	39	43.4	9.989901	0.272576

Ephemeris of Brook's Comet for the Return 1903-04.

[Computed by P. Neugebauer, A. N. 3868. Continued from p. 506.[

Berlin Midn. 1903.		R. A. h	m	s	Decl. °	′	″	log. r.	log Δ.
Jan.	1	23	9	14 35	−5	58	22.6		
	2		11	12 68	5	43	9.0	0.2949	0.33591
	3		13	11.22	5	27	53.5		
	4		15	9.98	5	12	36.2		
	5		17	8.94	4	57	17.1		
	6		19	8.10	4	41	56.4	0.2958	0.34394
	7		21	7.47	4	26	34.1		
	8		23	7.04	4	11	10.4		
	9		25	6.80	3	55	45.4		
	10		27	6.74	3	40	19.0	0.2969	0.35184
	11		29	6.88	3	24	51.4		
	12		31	7.20	3	9	22.8		
	13		33	7.70	2	53	53.1		
	14		35	8.37	2	38	22.5	0.2980	0.35961
	15		37	9.21	2	22	51.1		
	16		39	10.21	2	7	18.9		
	17		41	11.38	1	51	46.1		
	18		43	12.71	1	36	12.9	0.2993	0.36724
	19		45	14.20	1	20	39.3		
	20		47	15.84	1	5	5.3		
	21		49	17.63	0	49	31 2		
	22		51	19.55	0	33	57.0	0.3007	0.37473
	23		53	21.60	0	18	22 8		
	24		55	23.77	−0	2	48.7		
	25		57	26.06	+0	12	45.2		
	26		59	28.47	0	28	18.8	0.3022	0.38209
	27	0	1	30.99	0	43	52.0		
	28		3	33.64	0	59	24.6		
	20		5	36.40	1	14	56.4		
	30		7	39.26	1	30	27.5	0.3037	0.38932
	31		9	42.24	1	45	57.8		
Feb.	1		11	45.32	2	1	27.2		
	2		13	48.50	2	16	55.5		
	3		15	51.80	2	32	22.7	0.3054	0 39639
	4		17	55.20	2	47	48.7		
	5		19	58.70	3	3	13.3		
	6		22	2.30	3	18	36.5		
	7		24	6 00	3	33	58.3	0.3072	0.40335
	8		26	9.80	3	49	18.6		
	9		28	13.71	4	4	37.3		
	10		30	17.72	4	19	54.2		
	11		32	21.82	4	35	9.3	0.3091	0.41017
	12		34	26.02	4	50	22.5		
	13		36	30.32	5	5	33.7		
	14		38	34.71	5	20	42.8		
	15	0	40	39 20	+5	35	49.6	0.3111	0.41686

Elements of Asteroid (417) [1901 GN.]—In *A. N.* 3908 Mr. Bror Meurk of Stockholm gives the following elements of this planet, depending upon eleven observations:

Epoch = 1901 May 18.5 Berlin M. T.
M = 235° 25′ 05″.6
ω = 315 38 56 .4 } 1900.0
Ω = 84 38 07 .2 }
i = 15 24 51 .8 }
φ = 18 31 48 .3
μ = 727″.070
log *a* = 0.458954

Elements and Ephemeris of Asteroid (505) [1902 LL.]—In *A. N.* 3908 Mr. Hans Osten, of Bremen, gives the following elements and ephemeris of this planet, which was discovered by Mr. Frost on the Harvard photographs at Arequipa, Peru, Aug. 21.1902:

EPOCH 1902 AUG. 21.5 BERLIN M. T.

$M = 259°\ 38'\ 32''$
$\omega = 334\ 41\ 20$
$\Omega = 91\ 14\ 47$ } 1902.0
$i = 9\ 49\ 03$

$\phi = 14°\ 00'\ 01''$
$\mu = 811''.90$
$\log a = 0.42700$

Mr. Osten says that on Dec. 8 the planet will be over 2 magnitudes brighter than when it was discovered at Arequipa.

EPHEMERIS OF ASTEROID (505).

1903	R. A. h m s	Decl. ° ′	log r	log Δ
Dec. 2	5 17 49	−17 43.1		
4	15 53	17 54.6	0.3079	0.0225
6	13 55	18 06.3		
8	11 55	18 18.3	0.3083	0.0216
10	9 53	18 30.4		
12	7 51	18 42.7	0.3087	0.0224
14	5 50	18 55.2		
16	3 49	19 07.8	0.3092	0.0249
18	5 01 52	19 20.4		
20	4 59 57	19 33.0	0.3098	0.0290
22	58 07	19 45.9		
24	56 21	19 58.7	0.3104	0.0347
26	54 40	20 11.5		
28	53 07	20 24.3	0.3111	0.0418
30	51 39	20 37.1		
32	4 50 19	+20 49.8	0.3119	0.0503

New Asteroids.—The following have been added to the list of new planets since our last note:

	Discovered By	At		Local M. T. h m	R. A. h m	Decl. ° ′	Mag.
1903 MH	Dugan	Heidelberg	Sept.	22 13 41.7	0 32.4	+ 8 59	12.3
ML	Wolf	"		23 12 12.5	0 57.1	+ 8 53	11.8
MK	Wolf	"		24 13 23.2	1 08.7	+ 3 39	13.0
MM	Götz	"	Oct.	14 10 35.5	0 56.6	+ 5 48	12.9
MN	Dugan	"		20 11 08.5	1 57.0	+ 9 15	11.8
MO	Dugan	"		20 11 08.5	2 21.5	+12 13	12.5
MP	Dugan	"		20 11 08.5	2 41.3	+12 19	11.5
MQ	Wolf	"		20 11 53.1	0 51.9	+13 33	13.5
MR	Dugan	"		23 9 19.9	1 02.5	− 0 20	11.8
MS	Wolf	"		27 12 01.2	3 15.2	+12 50	13.0
MT	Wolf	"		27 12 01.2	3 27.3	+13 21	13.0
MU	Wolf	"		27 12 01.2	3 28.5	+14 59	13.5
MV	Wolf-Götz	"		27 14 21.9	3 15.3	+21 19	13.0

ML has later been found to be identical with (214) Aschera.

Nova Persei.—In *A. N.* 3910 Mr. K. Böhlin of Stockholm gives an account of four photographs of the region about Nova Persei, taken on the dates 1901 Nov. 12, 1901 Dec. 16, 1902 Jan. 16 and 1902 Feb. 4. The exposures were of 6, 8, 5½ and 8¾ hours duration respectively. Very excellent reproductions of the negatives accompany the paper.

VARIABLE STARS.

Minima of Variable Stars of the Algol Type.

[Greenwich Mean Time beginning with midnight. The hours greater than 12 are those of the afternoon. To obtain Eastern Standard time subtract 5 hours; for Central Standard subtract 6 hours, etc.]

U Cephei.

	d	h
Jan	1	3
	3	15
	6	3
	8	15
	11	3
	13	14
	16	2
	18	14
	21	2
	23	14
	26	2
	28	13
	31	1

Z Persei

Jan.	3	23
	7	1
	10	2
	13	3
	16	5
	19	6
	22	7
	25	9
	28	10
	31	12

Algol.

Jan.	1	11
	4	8
	7	5
	10	1
	12	22
	15	19
	18	16
	21	13
	24	9
	27	6
	30	3

λ Tauri.

Jan.	3	2
	7	1
	11	0
	14	22
	18	21
	22	20
	26	19
	30	18

R Canis Maj.

Jan.	2	1
	3	4
	4	7
	5	11
	6	14
	7	17
	8	20
	10	0
	11	3
	12	6

R Canis Maj.

Jan.	13	10
	14	13
	15	16
	16	19
	17	23
	19	2
	20	5
	21	8
	22	12
	23	15
	24	18
	25	21
	27	1
	28	4
	29	7
	30	10
	31	14

RR (R^2) Puppis

Jan.	1	0
	6	10
	11	21
	17	7
	22	17
	28	4

V Puppis.

Jan.	2	0
	3	11
	4	22
	6	9
	7	20
	9	7
	10	18
	12	4
	13	15
	15	2
	16	13
	18	0
	19	11
	20	22
	22	9
	23	20
	25	7
	26	18
	28	4
	29	15
	31	2

S Cancri

Jan.	9	11
	18	23
	28	10

S Antliæ.

Period $7^h\ 46^m.8$

Jan.	1	2
	2	1
	3	0

S Antliae

	d	h
Jan.	4	0
	4	23
	5	22
	6	22
	7	21
	8	20
	9	20
	10	19
	11	18
	12	18
	13	17
	14	17
	15	16
	16	15
	17	15
	18	14
	19	13
	20	13
	21	12
	22	11
	23	11
	24	10
	25	9
	26	9
	27	8
	28	7
	29	7
	30	6
	31	5

S Velorum.

Jan.	1	8
	7	6
	13	4
	19	3
	25	1
	31	0

δ Librae.

Jan.	2	21
	5	5
	7	13
	9	21
	12	5
	14	13
	16	20
	19	4
	21	12
	23	20
	26	4
	28	12
	30	20

U Coronæ.

Jan.	2	12
	5	22
	9	9
	12	20

U Coronae.

	d	h
Jan.	16	7
	19	18
	23	5
	26	16
	30	2

R Aræ.

Jan.	1	16
	6	2
	10	12
	14	23
	19	9
	23	19
	28	5

U Ophiuchi.

Jan.	1	15
	2	11
	3	7
	4	4
	5	0
	5	20
	6	16
	7	12
	8	8
	9	4
	10	1
	10	21
	11	17
	12	13
	13	9
	14	5
	15	1
	15	21
	16	18
	17	14
	18	10
	19	6
	20	2
	20	22
	21	18
	22	14
	23	11
	24	7
	25	3
	25	23
	26	19
	27	15
	28	11
	29	7
	30	4

Z Herculis.

Jan.	2	16
	4	17
	6	15
	8	17
	10	15
	12	16

Z Hercul. Cont.

	d	h
Jan.	14	15
	16	16
	18	15
	20	16
	22	15
	24	16
	26	14
	28	16
	30	14

RV (S^2) Lyræ.

Jan.	2	20
	6	10
	10	1
	13	15
	17	5
	20	20
	24	10
	28	1
	31	15

U Sagittæ.

Jan.	1	20
	5	6
	8	15
	12	0
	15	9
	18	18
	22	3
	25	12
	28	22

SY (X^3) Cygni.

Jan.	2	23
	9	0
	15	0
	21	0
	27	0

SW (V^3) Cygni.

Jan.	4	2
	8	16
	13	6
	17	19
	22	9
	26	23
	31	13

UW (Z^4) Cygni.

Jan.	1	9
	4	19
	8	6
	11	17
	15	4
	18	15
	22	2
	25	12
	28	23

Minima of Variable Stars of the Algol Type.—Continued.

W Delphini		W Delphini.		Y Cygni		Y Cygni		Y Cygni	
d	h	d	h	d	h	d	h	d	h
Jan. 2	13	Jan. 31	9	Jan. 6	10	Jan. 15	10	Jan. 24	10
7	9	Y Cygni		7	18	16	18	25	18
12	4	1	18	9	10	18	10	27	9
16	23	3	10	10	18	19	18	28	18
21	19	4	18	12	10	21	10	30	9
26	14			13	18	22	18	31	18

Variable Stars of Short Period not of the Algol Type.

	Minimum.		Maximum.			Minimum.		Maximum.	
		h		h			h		h
V Velorum	Jan. 1	1	Jan. 2	0	κ Pavonis	Jan. 16	12	Jan. 20	7
β Lyræ	1	17	5	0	V Centauri	16	23	18	10
δ Cephei	1	21	3	12	T Velorum	17	4	18	13
S Trianguli Austr.	2	11	4	13	T Vulpeculae	17	8	18	17
SU Cygni	2	12	3	20	SU Cygni	17	21	19	5
R Crucis	2	17	4	3	δ Cephei	18	0	18	15
W Virginis	2	22	11	3	V Carinae	18	2	20	6
T Velorum	3	6	4	15	RV Scorpii	18	4	19	14
T Vulpeculae	4	0	5	9	S Normae	18	4	22	14
S Muscae	4	11	7	22	V Velorum	18	13	19	12
S Crucis	4	12	6	0	S Crucis	18	14	20	2
V Carinae	4	16	6	20	R Crucis	20	4	21	13
ζ Geminorum	4	17	9	17	W Virginis	20	5	28	10
W Geminorum	5	2	7	17	W Geminorum	20	14	23	5
V Velorum	5	10	6	9	β Lyrae	21	2	24	4
V Centauri	5	23	7	10	S Triang. Austr.	21	10	23	12
RV Scorpii	6	2	7	12	SU Cygni	21	18	23	6
SU Cygni	6	9	7	17	T Vulpeculae	21	18	23	3
δ Cephei	7	6	8	21	T Velorum	21	19	24	4
T Vulpeculae	7	7	15	5	V Centauri	22	11	23	22
T Crucis	7	15	9	16	V Velorum	22	22	23	21
T Velorum	7	21	9	6	S Crucis	23	6	24	18
β Lyrae	8	4	11	6	δ Cephei	23	9	25	0
κ Pavonis	8	10	12	5	S Muscae	23	19	27	6
S Normae	8	10	12	20	RV Scorpii	24	6	25	16
T Vulpeculae	8	11	9	20	κ Pavonis	24	14	28	9
R Crucis	8	13	9	22	V Carinae	24	19	26	23
S Trianguli Austr.	8	18	10	20	ζ Geminorum	25	1	30	1
S Crucis	9	5	10	17	SU Cygni	25	14	26	22
V Velorum	9	19	10	18	R Crucis	26	0	27	9
SU Cygni	10	5	11	13	T Vulpeculae	26	4	27	13
V Carinae	11	9	13	13	T Velorum	26	11	27	20
V Centauri	11	11	12	22	V Velorum	27	7	28	6
RV Scorpii	12	3	13	13	β Lyrae	27	13	28	20
T Velorum	12	12	13	21	S Triang. Austr.	27	18	29	20
δ Cephei	12	15	14	6	S Normae	27	22	32	0
W Geminorum	12	20	18	11	V Centauri	27	23	29	10
T Vulpeculae	12	21	14	6	S Crucis	27	23	29	11
X Cygni	13	0	19	19	W Geminorum	28	8	30	23
TX Cygni	13	20	18	23	TX Cygni	28	13	33	16
S Crucis	13	21	15	9	δ Cephei	28	18	30	9
SU Cygni	14	1	15	9	X Cygni	29	9	36	4
S Muscae	14	3	17	14	SU Cygni	29	10	30	18
V Velorum	14	4	15	3	RV Scorpii	30	8	31	18
R Crucis	14	8	15	17	T Vulpeculae	30	15	32	0
T Crucis	14	8	16	7	T Velorum	31	1	32	10
β Lyrae	14	15	17	22	V Carinae	31	12	33	16
ζ Geminorum	14	21	19	21	V Velorum	31	16	32	15
S Triang. Austr.	15	2	17	2	R Crucis	31	20	33	5

Maxima of U Pegasi.

Period $4^h\ 29^m.8$. The minimum occurs $2^h\ 15^m$ after the maximum.

	d	h		d	h		d	h		d	h
Jan.	1	1	Jan.	9	3	Jan.	17	0	Jan.	25	1
	2	0		10	1		18	3		26	0
	3	3		11	0		19	1		27	2
	4	1		12	3		20	0		28	1
	5	0		13	1		21	3		29	4
	6	3		14	0		22	1		30	2
	7	1		15	3		23	0		31	1
	8	0		16	1		24	3			

Maxima of UY Cygni.

Period $13^h\ 27^m\ 21^s$. The minimum occurs $1^h\ 53^m$ before the maximum.

	d	h		d	h		d	h		d	h
Jan.	1	5	Jan.	9	2	Jan.	16	22	Jan.	24	19
	2	8		10	5		18	1		25	22
	3	11		11	8		19	4		27	0
	4	14		12	11		20	7		28	3
	5	17		13	13		21	10		29	6
	6	20		14	16		22	13		30	9
	7	23		15	19		23	16		31	12

Maxima of Y Lyræ.

Period $12^h\ 03.9^m$.

	d	h		d	h		d	h		d	h
Jan.	1	14	Jan.	9	15	Jan.	17	16	Jan.	24	17
	2	15		10	16		18	17		25	18
	3	15		11	16		19	17		26	18
	4	15		12	16		20	17		27	18
	5	15		13	16		21	17		29	18
	6	15		14	16		22	17		30	18
	7	15		15	16		23	17		31	18
	8	15		16	16						

New Variable Star 58.1903 Cygni.—This is announced by Mr. A. Stanley Williams in *A. N.* 3907. It is BD + 39°4379 and its position for 1855.0 is

R. A. $20^h\ 51^m\ 52^s.2$, Decl. + 39° 37′.1.

It varies from about $9^m.0$ at maximum to about $10^m.0$ at minimum. Sharply defined maxima occurred on Sept. 5.6 and Sept. 25.8, 1903 so that the period is about 20 days. Maxima may be expected Dec. 15, Jan. 4 and Jan. 24.

The Variable Star 4.1903 Draconis.—In *A. J.* 548 Mr. W. M. Reed gives an account of observations of seven minima of this Algol-Type variable at the Princeton Observatory, during the past summer and autumn, and calls attention to certain unprecedented irregularities in its light changes. Although the minima occur with great regularity, and satisfy the elements of Mr. Blajko with a correction of only 1.3 minutes, yet the magnitude at minimum is far from constant. In the seven minima observed the magnitude at minimum has ranged from 12.7 to 13.6. Also the shape of the light curve has undergone equally pronounced changes. Mr. Reed suggests that if the eclipsing body were a double star, in which the components were close together, the phenomena of the light curve could be in part explained.

Approximate Magnitudes of Variable Stars Nov. 10, 1903.

[Communicated by the Director of Harvard College Observatory, Cambridge, Mass.]

Name.	R. A. 1900. h m	Decl. 1900. ° ′	Magn.	Name.	R. A. 1900. h m	Decl. 1900. ° ′	Magn.
T Androm.	0 17.2	+ 26 26	14*f*	R Camel.	14 25.1	+ 84 17	9
T Cassiop.	0 17.8	+ 55 14	8*i*	R Bootis	14 32.8	+ 27 10	10*d*
R Androm.	0 18.8	+ 38 1	13*i*	S Librae	15 15.6	− 20 2	*s*
S Ceti	0 19.0	− 9 53	9*d*	S Serpentis	15 17.0	+ 14 40	12*d*
W Cassiop.	0 49.0	+ 58 1	*u*	S Coronae	15 17.3	+ 31 44	12
S "	1 12.3	+ 72 5	10*d*	S Urs. Min.	15 33.4	+ 78 58	8*i*
R Piscium	1 25.5	+ 2 22	11*d*	R Coronae	15 44.4	+ 28 28	6
R Trianguli	1 31.0	+ 33 50	7*i*	V "	15 45.9	+ 39 52	*u*
U Persei	1 52.9	+ 54 20	8	R Serpentis	15 46.1	+ 15 26	11*d*
R Arietis	2 10.4	+ 24 36	10*i*	R Herculis	16 1.7	+ 18 38	10*i*
o Ceti	2 14.3	− 3 26	9*d*	R Scorpii	16 11.7	− 22 42	*s*
S Persei	2 15.7	+ 58 8	9*d*	S "	16 11.7	− 22 39	*s*
R Ceti	2 20.9	− 0 38	11*d*	U Herculis	16 21.4	+ 19 7	12
U "	2 28.9	− 13 35	10*d*	R Ursae Min.	16 31.3	+ 72 28	*u*
R Persei	3 23.7	+ 35 20	*u*	W Herculis	16 31.7	+ 37 32	12*i*
R Tauri	4 22.8	+ 9 56	*f*	R Draconis	16 32.4	+ 66 58	12*d*
S "	4 23.7	+ 9 44	14*i*	S Herculis	16 47.4	+ 15 7	8*i*
R Aurigæ	5 9.2	+ 53 28	10*i*	R Ophiuchi	17 2.0	− 15 58	8*i*
U Orionis	5 49.9	+ 20 10	12*d*	T Herculis	18 5.3	+ 31 0	8*i*
R Lyncis	6 53.0	+ 55 28	8*d*	R Scuti	18 42.2	− 5 49	5*i*
R Gemin.	7 1.3	+ 22 52	10*d*	R Aquilae	19 1.6	+ 8 5	11*d*
S Canis Min.	7 27.3	+ 8 32	10*i*	R Sagittarii	19 10.8	− 19 29	10*i*
R Cancri	8 11.0	+ 12 2	7*d*	S "	19 13.6	− 19 12	*f*
V "	8 16.0	+ 17 36	*f*	R Cygni	19 34.1	+ 49 58	8*i*
S Hydrae	8 48.4	+ 3 27	*f*	RT "	19 40.8	+ 48 32	7*i*
T "	8 50.8	− 8 46	*f*	X "	19 46.7	+ 32 40	5*i*
R Leo. Min.	9 39.6	+ 34 58	8*d*	S Cygni	20 3.4	+ 57 42	14*f*
R Leonis	9 42.2	+ 11 54	8*d*	RS "	20 9.8	+ 38 28	7
R Urs. Maj.	10 37.6	+ 69 18	10*d*	R Delphini	20 10.1	+ 8 47	9*i*
R Comae	11 59.1	+ 19 20	*f*	U Cygni	20 16.5	+ 47 35	10*d*
T Virginis	12 9.5	− 5 29	*s*	V "	20 38.1	+ 47 47	14*f*
R Corvi	12 14.4	− 18 42	*s*	T Aquarii	20 44.7	− 5 31	13*f*
Y Virginis	12 28.7	− 3 52	*s*	R Vulpec.	20 59.9	+ 23 26	*u*
T Urs. Maj.	12 31.8	+ 60 2	8	T Cephei	21 8.2	+ 68 5	9*i*
R Virginis	12 33.4	+ 7 32	*s*	S "	21 36.5	+ 78 10	8*i*
S Urs. Maj.	12 39.6	+ 61 38	8	S Lacertae	22 24.6	+ 39 48	8
U Virginis	12 46.0	+ 6 6	*s*	R "	22 38.8	+ 41 51	*u*
V "	13 22.6	− 2 39	*s*	S Aquarii	22 51.8	− 20 53	12*d*
R Hydrae	13 24.2	− 22 46	*s*	R Pegasi	23 1.6	+ 10 0	11*d*
S Virginis	13 27.8	− 6 41	*s*	S "	23 15.5	+ 8 22	10*i*
R Can. Ven.	13 44.6	+ 40 2	10*d*	R Aquarii	23 38.6	− 15 50	9*i*
S Bootis	14 19.5	+ 54 16	9*i*	R Cassiop.	23 53.3	+ 50 50	11*i*

NOTE:—*f* denotes that the variable is probably fainter than the magnitude 13; *i*, that its light is increasing; *d*, that its light is decreasing; *s*, that it is near the Sun; *u*, that its magnitude is unknown.

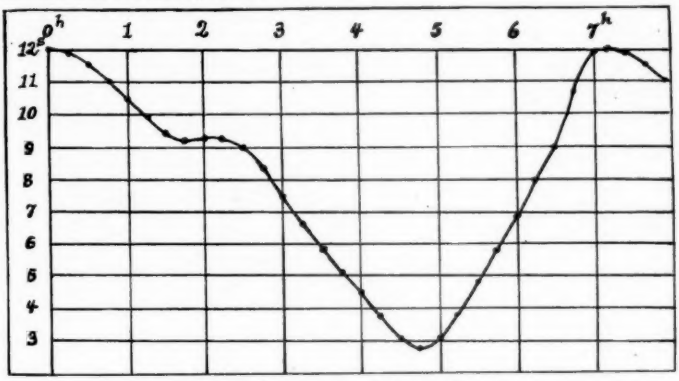
Derived from observations made at the Halstead, McCormick, Eadie and Harvard Observatories, Nov. 10, 1903.

New Variable 59.1903 Cygni.—The star which was announced last month by Dr. Wolf as possibly a *nova* has been numbered 59.1902.

Long Period Variables.—In *A. N.* 3909 Mr. E. Jost gives a considerable list of observations of long period variables, made at Gotta during 1903.

Elements of η Aquilæ.—In *A. N.* 3911 Mr. M. Luizet of St. Genis-Laval, France, gives new elements of this well-known variable, derived from his own observations from June 18, 1898 to Oct. 7, 1902, together with the previously published observations extending back to 1784. The new elements are:

$$\left.\begin{matrix}\text{Maximum } 2396168.732 \\ \text{Minimum } 2396166.359\end{matrix}\right\} \text{J. D. Gr. M. T.} + 7.176382^{d}\text{E} + 0.14^{d} \sin (0°.044\text{E} + 304°.)$$



THE LIGHT CURVE OF η AQUILÆ (LUIZET.)

The accompanying diagram shows the light curve as determined by Mr. Luizet. The light scale is derived from the following five stars:

ν Aquila	0.0	steps
ι "	4.4	"
ε "	6.6	"
β "	9.1	"
δ "	14.6	"

GENERAL NOTES.

It will interest our readers to know that important changes are to be made in the size and matter of this magazine beginning with the January number, 1904. We have been working towards this important change since *Astronomy and Astrophysics* was discontinued. We now have our own office for composition, and we are associated with the most complete print shop that we know of in any small city, as regards fine presses and type setting machines. We also have, within reach, engravers that are unsurpassed anywhere in all the lines we use. As an illustration of the fine work we will be able to present when needed attention is called to the neat and almost perfect picture of the late Prosper Henry, astronomer of the Paris Observatory, which is the frontispiece to this issue.

We have also spent some time lately in conversing with experienced astronomers on the changes about to be made. We are delighted to find the cordial and helpful coöperation which has been offered us on every hand, with the one caution that comes from some conservative friends, in the query, Can you stand this increased expense from the support you are likely to get? Our reply has been in every case, We believe we can.

We are not now ready to say just what these changes are to be, for they have not yet been fully worked out in detail. But something may be indicated to show the direction of them. We are to deal with POPULAR ASTRONOMY on a larger scale. The work in astronomy that is now going on should be reviewed in a popular way, so that any intelligent reader may get readily the meaning of it. General news and a current run of celestial phenomena will be kept as now. In a word, a current popular review of astronomy is the aim. We hope for large help from every source.

Auroral Phenomena.—A rather brilliant auroral display took place here on Saturday, October 31st, between 5:30 and 6:30 P. M.

I first saw it at about 5:55, when a bank of pearly, greenish light was visible five or six degrees above the horizon, extending from the northwest to the northeast. Streamers could be traced nearly to the zenith, and changed so rapidly as to suggest heat-lightning.

At 6:10 the illumination was much less brilliant, and at 6:30 no trace of it remained.

It is of interest to note that the great group of sunspots was upon the Sun's meridian that day, and that another large group, surrounded by extensive faculæ, had just appeared upon the eastern limb. ANNE S. YOUNG.

Transit of Jupiter's Fourth Satellite.—Friday, October 30th, a dark transit of Jupiter's fourth satellite was observed similar to that of the third satellite seen on September 28th and described by Mr. Barnes in the November POPULAR ASTRONOMY. The ingress of the satellite took place at $8^h\ 50^m$ (E. Standard Time), when it became invisible upon the background of the planet. An hour later it was plainly visible as a dark round spot upon the planet's disk. It was decidedly darker than the equatorial belt. ANNE S. YOUNG.

Bright Meteor.—On the evening of November 9 about $7^h\ 25^m$, I saw a very bright meteor; it started a little south of Vega, and fell almost directly downward, apparently, and burst about 30° above the horizon. At first, its color was yellow, and when it burst its color was orange and red. It left a trail of bright points and light. Its size seemed to be about that of a two-pound sky rocket, and its appearance was much the same. CURTIS H. THOMAS.

TRAER, Iowa, Nov. 9, 1903.

Auroral Bands.—Chancing to be in the public library in Minneapolis, Minn., I read in the last issue of POPULAR ASTRONOMY, with interest, the account of Rev. F. Campbell of the phenomena seen by him in the region of the Adirondack mountains, in the state of New York. This recalled to my mind that I once saw such a sight as he describes. I cannot with certainty place the year or the time of the year, but think it was in 1867. I was then in Ste Marie, Green Lake county, Wis., near the Fox River, about fifteen miles from Ripon.

MINNEAPOLIS, Minn., Nov. 6, 1903. T. LA F. SMITH.

The New Observatory of Amherst College.—On Oct. 27-28, Professor Todd and his assistant, Mr. R. H. Baker, began the first series of observations in the new Observatory of Amherst College. They were made with the old Gambey meridian circle, which seems to have been the first transit purchased as part of the permanent equipment of an American Observatory. It was bought in Paris by Professor Hovey in 1831, though not mounted in the old Observatory, now dismantled, till 1847. The largest telescope of the new Observatory is an 18-inch by Clark, now nearly completed. The equipment includes also a 12¼ inch photographic objective, a 12-inch speculum, a 6⅜ inch Pistor & Martin's combined transit and zenith telescope, and several smaller instruments.

Dark Transit of Jupiter's Fourth Satellite.—In the ever varying aspects of Jupiter's satellites it is seldom that they present a configuration so picturesque as that assumed on the evening of October 30th, at $7^h\ 45^m$ Central Standard Time when Nos. I, III and IV were seen within 6″ of contact with the primary planet.

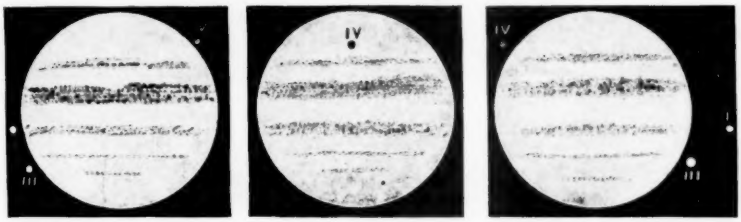


Fig. 1. Before Contact 7h 45m P. M. Fig. 2. Dark Transit of No. IV 9h 34m P. M. Fig. 3. After Emergence 11h 22m P. M.

TRANSIT OF JUPITER'S DARK SATELLITE.

Nos. I and III, in their almost even race to occultation, shown with their usual brightness; while No. IV, leading in the race, approaching contact on the opposite side, fell so far short of its usual albedo that a dark transit was at once predicted. Four minutes later as the satellite cut into the disk the prediction was verified, the dark figure projected on the disk standing out clear cut and prominent. As it traversed the disk in 38 degrees S. Latitude, the black image seemed to increase in density, being easily followed to egress, after which it continued so dim that it was seen with difficulty in the five-inch glass even when at a distance of 10″ from the disk of Jupiter. Certainly its brightness was less than 1/5 that of normal.

Meanwhile Nos. I and III had emerged from occultation, as shown in Figure 3.

Figure 1 shows the three satellites before contact. Figure 2 shows the dark image of No. IV at central meridian passage.

WILLIS L. BARNES.

CHARLESTOWN, Ind.

Auroral Arches.—Since the publication of my recent article on the wonderful phenomenon seen in the sky, Aug. 21st, I have received two letters, one from the librarian of Colby College, Waterville, Me., and the other from Rev. A. B. Hervey, of Bath, Me., both saying that they had seen the same phenomenon, the former from Boothby Harbor, Me., the latter from Ossipee Mountain, New Hampshire; the latter says it was also observed in Bath, Me., as he learned on returning home. The latter also says that Miss Whiting, Professor of astronomy at Wellesley College was present and saw the phenomenon; from her you might get some particulars such as I have not given you. Rev. Mr. Hervey draws a rough sketch for me, showing that his arch was not altogether like mine. You have doubtless seen the drawing in the *Popular Science Monthly* for October, illustrating the article there on the same phenomenon as seen from York Harbor Me., I believe.

In each case the date seems to be the same, Aug. 21st; but Bath, Me., is close to 300 miles east of my point of observation in the Adirondacks, (Cranberry Lake), and I cannot think that the arch which I saw was sufficiently elevated to

be seen at that distance. It did not seem more than two or three miles high at the zenith. Moreover, it lacked the comet-like pendants described in the *Popular Science Monthly*, and the serrated edge spoken of and drawn in Rev. Mr. Hervey's communication to me. It seems to me therefore reasonable to believe that there were at least two arches, entirely independent of each other, except as each of them was caused by magnetic conditions which happened to be identical at the same time in the northern Adirondacks and in Maine, or, possibly, throughout an entire section of country sufficiently wide to take in both these locations. While this magnificent arch of light was not a rainbow, yet, for purpose of illustration, it is appropriate to say that a rainbow seen in the Adirondacks would not be seen in Maine; but if the weather happened to be identical in both regions, two distinct yet similar rainbows might be seen at about the same time in both places. So with this arch. Rev. Mr. Hervey says that his arch passed practically through the zenith; so did mine; but if my estimate of the arch's height is even approximately correct, then, being seen reaching the zenith in the Adirondacks, it certainly would be seen, if at all, far west of it in Maine, which was not the case. For these reasons I conclude that the two arches, though seen the same night, and doubtless produced by similar conditions, were not identical. Hence the wonder is doubled.

FREDERICK CAMPBELL.

BROOKLYN, N. Y., 428½ Clinton Street.

The Orbit of β 216.—In *A. N.* 3908 Mr. W. Doberck gives a new determination of the orbit of this double star from observations extending from 1876 to 1901. The period obtained is 45.9 years. An ephemeris is given for the years 1902 to 1910.

Elements.	Ephemeris.		
° ′	t	P.A.	Dist.
		°	″
$\Omega = 135\ \ 44$			
$\lambda = 291\ \ 26$	1902.5	290.9	2.21
$\gamma = 49\ \ 44$	3.5	288.0	2.26
$\epsilon = 0.6184$	4.5	285.1	2.29
$P = 45.90$ years	5.5	282.3	2.31
$T = 1891.56$	6.5	279.6	2.33
$a = 1''.93$	7.5	276.9	2.34
Retrograde.	8.5	274.2	2.33
	9.5	271.4	2.32
	1910.5	268.6	2.30

The Orbit of ϕ Ursæ Majoris.—In *A. N.* 3912 Mr. Doberck also gives elements of the close binary ϕ Ursæ Majoris, using all available observations from 1842 to 1902. An ephemeris for the next ten years is also given.

Elements.	Ephemeris.		
° ′	t	P.A.	Dist.
		°	″
$\Omega = 186\ \ 30$			
$\lambda = 342\ \ 9$	1903.4	294.0	0.33
$\gamma = 14\ \ 37$	4.4	296.9	0.34
$\epsilon = 0.4379$	5.4	299.5	0.35
$P = 99.70$ years	6.4	302.1	0.36
$T = 1882.46$	7.4	304.6	0.36
$a = 0''.32$	8.4	306.9	0.37
	9.4	309.2	0.38
	10.4	311.4	0.39
	11.4	313.5	0.39
	1912.4	315.6	0.40

The Proper Motion of θ Cancri.—In 1783 Herschel I noted a distant companion to the 5½ magnitude star θ Cancri and included it in his catalogue as HV 59. He did not measure the position-angle but gave the distance as 44″.87. Later, about 1830, Herschel II entered it as No. 2452 of his sixth catalogue, rating the small star as 10^m, and estimating the distance 60″. The first accurate measure is by Knott in 1862. He called the companion 11^m.5. I have recently re-measured this as follows:

1892.947	60°.9	63″.15
2.985	60 .8	63 .26
3.028	60 .8	63 .01

The small star I called 11^m. The measures which can be used for the determination of the relative motion are:

1862.31	59°.3	58″.41	1*n*	Knott
1880.14	60 .0	60 .84	3*n*	B
1898.15	60 .4	62 .55	2*n*	Doolittle
1902.99	60 .8	63 .14	3*n*	B

The distance of Herschel I is obviously too small and by about 5″.

The proper motion of θ Cancri is given:

Auwers	0″.088 in 235°.4
Newcomb	0 .088 in 219 .3

The four sets of measures give the probable relative movement of the principal star considering B as fixed, as 0″.119 in 257°.4 from which it would appear that the value derived from meridian positions is too small, or that the faint star has a considerable movement of its own, and in nearly the opposite direction.

Total Eclipse of the Sun May 18, 1901.—The report of the Dutch Expedition to Karnag Sago, Sumatra has just reached us. It is a pamphlet of 27 pages, printed in English with five full page illustrations. It is published by the eclipse committee of the Royal Academy of Amsterdam and it gives a full and detailed account of the expedition. This report was written by A. A. Nijland, Sc. D., Professor of Astronomy, Utrecht, March 1903.

This report gives the details of the expedition but does not publish the results of the astronomical work, except mostly of a negative kind. We have not the first preliminary report that probably gives some results of the observations made. From the statements made on page 26, it is probable that a further report will be made concerning the results of the prismatic camera and the amateur observations.

It is reported that during totality, "the blue sky was very pale and greyish; the scenery was illuminated by the well-known dull, gloomy, ghastly eclipse light. The clouds of 50° west of the eclipsed Sun looked fallow, or had a dingy orange tint. Around the inky black Moon the double *fish-tail* of the brilliant, silvery corona was visible through the gaps in the cirrus clouds; a most glorious sight, never to be forgotten. The southern border of the eastern *fish-tail* pointed to two brilliant stars, Venus and Mercury."

"No noise was heard, the Malay population having been warned by Mr. Van Loghern, assistant resident van Painan, to keep quiet, and not to hinder the observations by screaming as they were likely to do. *Kalongs* (great bats) are said to have left their hiding places, as if it were night. The curious 'chromatic bird,' we heard every evening in the camp, sang out of time. On the native population of the camp, the eclipse evidently did not make a very strong impression; when my Malay servant was asked what he thought of the *grahana matahari*, he simply answered, 'gelap, (dark)."

The results as far as we know are, that no shadow-bands were observed; Venus, Mercury, Aldebaran and a few stars in Perseus were visible, that the spectroscope, photometer and the small spectrograph gave no results. The work with the large spectrograph was an entire failure.

There are other parts of the work of the expedition that probably have given useful results; these are promised later.

The outfit was a large one, and the equipment of instruments ample and the plan of work especially modern in eclipse science. We presume later reports will be fruitful in result.

An Auroral Arch.—At 8:45 P. M. the position of the (auroral) arch at Poplar, Montana was as described by Dr. Campbell or perhaps a little farther south, when first seen by me. I soon observed that although the brightest part of the arch was about 40° from the east point of the horizon the eastern part for at least 30° from the horizon was becoming fainter and that the east part was fading. The arch then extended visibly to my poor eye within about 10° of the horizon at the east and within 5° at the west. I soon observed that the eastern part of the arch was rapidly moving south among the stars. At an altitude of 15° final observation it had, I think, moved over 15° before it became so faint I could not see it. I soon after observed that all parts of the arch were moving south. By 10 P. M. the only part of the arch visible to me consisted of a few patches of considerable size but faint extending from the meridian west about 45°.

I could see a rather conspicuous auroral display in the northern part of the heavens the entire time of observation, but aside from the arch I did not observe anything remarkable about it except the rapid variations in the quantity of light and rapidity of motion in both of which respects I have seen several auroras that at least equalled it. The great amount of light given by the arch, greater, I think, than that given by the Moon when 24 hours old, may have led me to underate the brightness of the northern display. A. W. WILLIAMSEN.

AUGUSTANA COLLEGE AND THEOLOGICAL SEMINARY,
Rock Island, Ill., Oct. 26, 1903.

Aurora August 21, 1903.—The reports of the aurora of August 21st which have appeared in the last two issues of your magazine have suggested to me that I report what was seen that night at Wayne, Pa., latitude N. 40° 3′, longitude W. 75° 28′.

There was a display of the aurora between 8 and 9 o'clock which I did not see, but from all the information I can gather it was lower down in the sky and much fainter than the one later. Shortly after 10 o'clock a friend called me out to witness one of the most peculiar displays I have ever seen. The light was milky white, without any suggestion of color, and appeared in the form of long streamers or columns radiating from an invisible semi-ellipse over the northern horizon. The columns were entirely separated, even at the bottom, and were entirely clear of the horizon except at the extreme ends of the curve. The highest part of the base of the columns was just below Theta Ursa Majoris. The light rolled up these columns like clouds of white smoke, at times lifting the tops of the columns to twice their ordinary height, for a moment, and then sinking down again. The bottom of the columns appeared to remain stationary except that the whole display had a very slow rotation towards the west.

A very few minutes watching showed that the columns were passing slowly

across the stars. The columns reached up into the bowl of the big dipper and frequently passed above Alpha and Delta. Several times they reached to Lambda and once to Kappa Draconis. By 11 o'clock it was fading away and before midnight the display was entirely over. HENRY G. BLATCHLEY.

WAYNE, Pa., Oct. 29, 1903.

The Great Sunspot.—To telescopic observers of the surface of the Sun it has been evident since September 1902, that the periodic inactivity of sunspot zones had passed, and that a slow but steady increase of solar disturbance had set in.

The spots that first appeared were small or faint in tint, but on the 5th of this October, a large group was inside the southeast limb and as it advanced centrally, developed into the most extensive area of activity that has discolored the glowing luminary since September 1898. When the eastern section was still in contact with the limb, the fore-shortened penumbra appeared as parallel lines slanting in a northeast direction; and on the 6th, 7 nuclei were seen to be strewn over the branching tracts. On the following morning they numbered 16, and the group was distinctly visible to the naked eye. It then measured about 110,000 miles in length and 30,000 in average width, but when free from foreshortening on the 11th of October, the apparent size was increased at least 20,000 miles. The central parts were in south latitude 35°.

The tree-like form of the penumbra had become more compact, though still it included several clear photospheric tracts, while the umbræ were larger and fewer in number. The morning of Oct. 12th showed that during the previous

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LARGE SUN-SPOT, OCT. 5, $12^h\ 30^m$ P. M.
SCREEN IMAGE.

LARGE SUN-SPOT, OCT. 8, 9 A. M.
SCREEN IMAGE.

hours activity on a vaster scale had set in, as a wide oblong division rent the penumbral centre. The intruding photospheric tract was about 30,000 miles in width, the evenness of its edges being a remarkable feature. Minor changes were evident in these initial footprints of a returning maximum during the following five days. The most easterly half of the disturbed area was still distinctly visible inside the west limb on the 17th, but on the 18th no trace of it was discernible in a four-inch telescope. On account of distance from the solar equator its return will not be due until the 1st of November. At the present hour (noon, October the 31st), there is no marking on the southeast limb. A group of half the

size appeared in south latitude 20 degrees on the 25th, and in the northern hemisphere another appeared on the 29th, which are additional proof that this long deferred maximum has arrived.

A daily record of the Sun's surface in September last shows that the great spot was a new formation as there was no marking on that tract of the solar disk during the previous rotation.

The usual sunspot cycle which includes the phases of increase and decrease lasts for about eleven years and two tenths, but the recent period has had a duration of fully twelve years. ROSE O'HALLORAN.

SAN FRANCISCO, Oct. 31st, 1903.

The Leonid Meteors at Yerkes Observatory.—There were but few Leonids this year according to the observations made here. Unless the display occurred in the day time, it would seem that the meteor swarm must be essentially past the Earth's orbit.

Careful watch was kept on the nights of November 13th and 14th. The night of the 15th was cloudy throughout. An irregular watch was kept on the night of the 12th from $11^h\ 0^m$ until about $15^h\ 0^m$ but no Leonids were seen.

Nov. 13.

The 13th was partly cloudy but it cleared at 8:30 and then clouded densely at $9^h\ 0^m$. In the interval no Leonids were seen. At $13^h\ 0^m$ though the sky was cloudy, frequent clear spaces passed by, but no meteors were seen in these as late as $13^h\ 30^m$ when the sky was again entirely obscured. At $15^h\ 0^m$ the sky suddenly cleared and remained clear until daylight. At this time a first magnitude meteor, probably a Leonid, was seen in the low northeast. $16^h\ 30^m$ in the interval of 1½ hours several meteors were seen, but they were not Leonids. They seemed to have a radiant somewhere near Orion. In the next 15^m one small meteor was observed but it was not a Leonid. $17^h\ 5^m$ no more meteors. A crescent moon did not materially interfere. A watch from $17^h\ 20^m$ to $17^h\ 30^m$ showed no meteors.

Nov. 14.

Cloudy until $13^h\ 0^m$ when the clouds partly cleared away. In the next half hour five 6^m meteors were seen only one of which was possibly a Leonid.

$13^h\ 50^m$. Up to this time no meteors were seen since last record. But at this time a 3rd magnitude Leonid with the characteristic bluish green streak 4° long, shot from near β Canis Minoris towards Rigel with a path about 20° long.

$14^h\ 5^m$. A large white meteor, as bright as Sirius, descended due south for 25° from a point between the Pleiades and Hyades. Not a Leonid.

$14^h\ 10^m$. Sky covered with thickish mist. Five minutes later the stars were all observed except in the low south.

$14^h\ 45^m$. Sky clearing.

$14^h\ 55^m$. All the southern half of sky clear.

$15^h\ 55^m$. Sky misted over again; only the bright stars visible. This soon thinned down.

$15^h\ 25^m$. A 5^m Leonid south of Sirius.

$15^h\ 30^m$. A 4^m Leonid passed 15° S. E. of Sirius.

$15^h\ 40^m$. Sky clear everywhere and so remained until daylight. At the above time a 6^m Leonid passed by Procyon.

At $15^h\ 52^m$ five Leonids suddenly appeared within 20° west of the radiant. They followed each other with extreme rapidity, indeed they were essentially all visible at the same moment, the extreme interval being something like two sec-

onds. One was of the 4m—the others of 5m or 6m. Each left the regulation Leonid streak. These were evidently a small group traveling close together. This peculiarity of grouping is a frequent occurrence in meteoric showers.

15h 57m. A 4m Leonid, with streak, shot towards Orion. Near this time a 6m meteor was seen in the south. Probably not a Leonid.

16h 12m. Two faint ones seen since last record.

16h 25m. No more up to now. Quit observing for 5m until 16h 30m.

16h 45m. In the interval three small meteors were seen. Not Leonids.

16h 58m. One Leonid near Sirius. Two others—not Leonids seen just before this.

17h 02m. Stopped here until 17h 10m.

17h 40m. No meteors in the interval. Sky whitening with dawn.

18h 05m. Watched for 5m here. No more meteors. Sky white.

During these observations the southern half of the sky was kept under observation—with frequent observations of the entire sky. Preparations were made for photographing the Leonids on Nov. 14, but the scarcity of meteors did not warrant the exposures.

E. E. BARNARD.

YERKES OBSERVATORY, 1903 Nov. 16th.

Leonids at Leander McCormick Observatory.—The Leonids were observed here on Nov. 12, 14 and 15. The following table gives the result of the count:

	Time				Leonids	Others	Total	Remarks
	h	m	h	m				
1903 Nov. 12	14	35—15	0		0	5	5	Clear. Moon.
	15	0—16	18		1	8	9	" "
Nov. 14	12	28—13	0		3	2	5	Hazy.
	13	0—14	0		5	6	11	"
	14	0—15	0		6	3	9	Clear.
	15	0—16	0		16	9	25	Clear to 16h .5.
	16	0—17	0		19	5	24	Sky ½ clear.
	17	0—17	28		6	0	6	Cloudy.
Nov. 15	12	39—13	0		7	3	10	Smoky.
	13	0—14	0		22	3	25	"
	14	0—14	34		5	0	5	Cloudy.
	15	0—16	0		28	7	35	Clear.
	16	0—16	58		16	2	18	Clear to 16.3, then cloudy.
Total					134	53	187	

A large proportion of the Leonids were bright, leaving persistent trains that lasted from ½ to 4 seconds. The prevailing color was orange, with some green and an occasional red one.

The brightest meteor was Nov. 14, 16h 54m 18s. The explosion of this meteor only was seen, and this through a rather thick cloud. It was estimated at many times brighter than Venus; a closer estimate being impossible. On Nov. 15, 13h 17m 15s a Leonid as bright as Venus was observed. On Nov. 15, a 2m stationary meteor gave the radiant at α 150°.8, δ + 22°.0. Other meteors plotted gave the same position. The radiant on Nov. 14, was in practically the same position. On Nov. 14, I was assisted by Mr. J. P. Smith of this University, and the tables give our combined results. On the other two nights I observed alone. As will be seen from the notes above the weather on the whole was very unfavorable during a large part of the time. No doubt a great number of meteors were missed from this cause.

CHARLES P. OLIVIER.

STUDENTS' OBSERVATORY, University of Va.

The Leonids of 1903, at the University of Illinois.—Watch for Leonids was kept by the writer on November 14th, 1903. The nights of Nov. 13th and 15th were cloudy but on the 14th the sky was perfectly clear. As there were no signs of a large display I remained indoors and watched from a large east window. Following are the data of the half hourly counts:

Astronomical Date 1903	Central Standard Time.				Magnitudes of Leonids.					Total Leonids	Other Meteors
	h	m	h	m	<1	1	2	3	4		
November 14	13	00—	13	30	1	1	1	0	0	3	2
	13	30—	14	00	0	2	1	0	0	3	3
	14	00—	14	30	0	0	1	1	0	2	0
	14	30—	15	00	0	0	0	0	0	0	0
	15	00—	15	30	0	1	0	3	0	4	3
	15	30—	16	00	0	1	2	0	0	3	0
	16	00—	16	30	0	0	0	1	0	1	1
	16	30—	17	00	0	1	2	0	1	4	0
Total in 4 hours					1	6	7	5	1	20	9

The observer's attention was kept on the Sickle and no very faint meteors were seen. Until about $15^h\ 30^m$, when the moonlight began to be noticeable, there would have been no difficulty in seeing Leonids much fainter than those recorded.

JOEL STEBBINS.

UNIVERSITY OF ILLINOIS OBSERVATORY,
URBANA, Ill., Nov. 18, 1903.

Knowledge Diary and Scientific Handbook for 1904.—We have used the Knowledge Diary and Scientific Handbook for the past three years with much satisfaction. The new volume for 1904, as heretofore, will give a whole page for each day of the year for diary purposes. The whole volume contains about 500 pages, and presents original articles by scientific specialists in photography, astronomy, natural history, meteorology, physics, microscopy, etc., etc. E. Walter Maunder shows how the camera is applied to astronomy with illustrations. M. I. Cross does the same in regard to microscopy, and R. B. Lodge, in natural history. Practical meteorology is presented by William Marriott of the Royal Met. Society; Ed. Edser gives the optical constants of lens combinations; M. I. Cross, some uses of a microscope; E. Walter Maunder, Practical work with a small telescope; E. E. Markwick, The observations of the variable stars. There are also charts illustrating the paths of the planets for the year, especially prepared for this book, full astronomical notes and useful tables, with a run of important celestial phenomena for the year. The star maps for each month are a help to those who intend to make a study of the outlines of the constellations for the whole year. This is a delightful exercise and will mean much to any student who would follow it up for one year. This form of Diary is commended because it has so much of real practical worth to any and all naturally interested in its contents.

Radium in the Sun.—Mr. J. Joly in October *Nature*, p. 572, says: The arguments in favor of supposing that this element (Radium) exists in the Sun are: (1) The presence of radium in the Earth; (2) the high atomic weight of radium; (3) The presence of helium in the Sun; (4) Arrhenius' theory of the Aurora Borealis; (5) The fact that the estimate of the duration of the solar heat from the dynamical source appears to run counter to geological data.

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